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Issued December 19, 1908.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF PUBLIC ROADS—BULLETIN No. 33.
LOGAN WALLER PAGE, DIRECTOR

ROAD MATERIALS OF SOUTHERN AND EASTERN MAINE.

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BY HENRY LEIGHTON AND EDSON S. BASTIN,
U. S. GEOLOGICAL SURVEY.

PREPARED IN COOPERATION BETWEEN THE U. S. GEOLOGICAL SURVEY, THE STATE SURVEY COMMISSION OF MAINE, AND THE OFFICE OF PUBLIC ROADS.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1908.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Public Roads,
Washington, D. C., May 16, 1908.

Sir: I have the honor to transmit herewith the manuscript of a preliminary report on the hard-rock road materials of southern and eastern Maine, by Mr. Henry Leighton and Mr. Edson S. Bastin, of the U. S. Geological Survey. This bulletin will form the first of a series which will be prepared in cooperation with this Office having in view the description, location, and testing of available road materials in the different States. I recommend that it be published as Bulletin No. 33 of this Office.

Respectfully,

L. W. Page,
Director.

Hon. James Wilson,
Secretary of Agriculture.

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THE ROAD MATERIALS OF SOUTHERN AND EASTERN MAINE.

INTRODUCTION.

The field observations forming the basis of this report were made principally by Mr. Henry Leighton under the general direction of Mr. E. S. Bastin and of Prof. Leslie A. Lee, State geologist of Maine. The field work extended over a period of two months in the summer of 1907, the cost being shared equally by the State survey commission of Maine and the U. S. Geological Survey. The physical and microscopic tests to determine the road-making value of the samples collected were made by the Office of Public Roads of the U. S. Department of Agriculture. Acknowledgment is due to Mr. Paul D. Sargent, State commissioner of highways, for valuable advice in the field work.

The area reported upon includes only that portion of Maine lying south of about latitude 45° 30′. The portion lying to the north is sparsely populated and the problem of road materials there has not yet assumed the importance that it has farther south. The time and funds available for the work precluded anything more than a reconnaissance investigation. To the results of these studies has been added the more precise information obtained from the detailed geologic studies completed or at present in progress in the Penobscot Bay, Rockland, Frenchmans Bay, and Eastport regions of Maine.

At the present time the principal source of road material in Maine is the gravels which occur in abundance in nearly all parts of the State; and in most of the rural districts where the character of the traffic and the funds available do not warrant large expenditures for road building, the gravels will probably always remain the principal material relied upon. Because of the great abundance of the gravels and their irregular distribution an adequate study of them would involve a large expenditure of time and money. The observations on gravels, therefore, reported in this bulletin, are mostly incidental to the study of the hard-rock road materials, except where detailed geologic studies for folio publication have been made.

Since there is wide variation in the road-making quality of different gravels, detailed studies of them are highly desirable and important. Their distribution and the location of all gravel pits have been shown

in detail on the Surficial Geology Sheet of the Rockland Quadrangle[a] and in accordance with plans recently completed for cooperation between the Office of Public Roads and the U. S. Geological Survey, detailed studies, not only of the gravels but of the hard-rock materials available for road construction, will be made in all regions whose geology is mapped in detail for folio publication.

Especial attention has been devoted in the present report to the road materials situated near the large cities and to deposits favorably located for shipment either by rail or by water.

GENERAL GEOLOGY OF SOUTHERN AND EASTERN MAINE.

The portion of Maine dealt with in this report may be characterized briefly as a region of metamorphosed sediments originally clayey in composition, which have been extensively intruded and injected by granitic rocks. With the argillaceous or originally clayey sediments are associated here and there small amounts of crystalline limestone and quartzite (altered sandstone), while with the true granites are associated small areas of coarse-grained, igneous rocks and of diorites and gabbros rich in the dark-colored iron-bearing minerals. In the Penobscot Bay region as well as in eastern Washington County there are also considerable amounts of volcanic rocks, lava flows, and tuffs, both of the dark-colored basic[b] variety and of the light-colored acid[b] variety. Throughout most of the State small dikes of dark-colored basic rock, diorite and diabase, are encountered. The majority are under 5 feet in width, though occasionally reaching 20 or 30 feet.

Detailed geologic studies in the Penobscot Bay region have shown that the metamorphosed sediments there are probably of Cambrian and Cambro-Ordovician age, and it is probable that the metamorphosed argillaceous sediments occupying such large areas in the northern part of the region under discussion are also largely of this age. (See Plate I.) The earth movements resulting in their metamorphism probably took place at the close of Ordovician times. The granites were intruded in a molten condition into the sedimentary rocks in late Silurian or early Devonian times. The volcanic rocks range in age from Cambrian to Silurian, those older than Silurian having been affected by dynamic metamorphism as were the

[a] U. S. Geol. Survey, Geologic Atlas U. S., folio No. 158, 1908. These folios may be obtained by addressing the Director, U. S. Geological Survey, Washington, D. C., and inclosing the price, 25 cents per copy, in money or post-office money order (not in stamps).

[b] The terms basic and acid as applied to igneous rocks are convenient and will be frequently used in this report. The basic igneous rocks are usually dark-colored and are characterized by an abundance of hornblende, pyroxene, biotite, or other iron-bearing minerals usually associated with feldspar but with little or no quartz. The acid igneous rocks are light-colored and are characterized by a relative scarcity of dark-colored, iron-bearing minerals and an abundance of quartz and feldspar.

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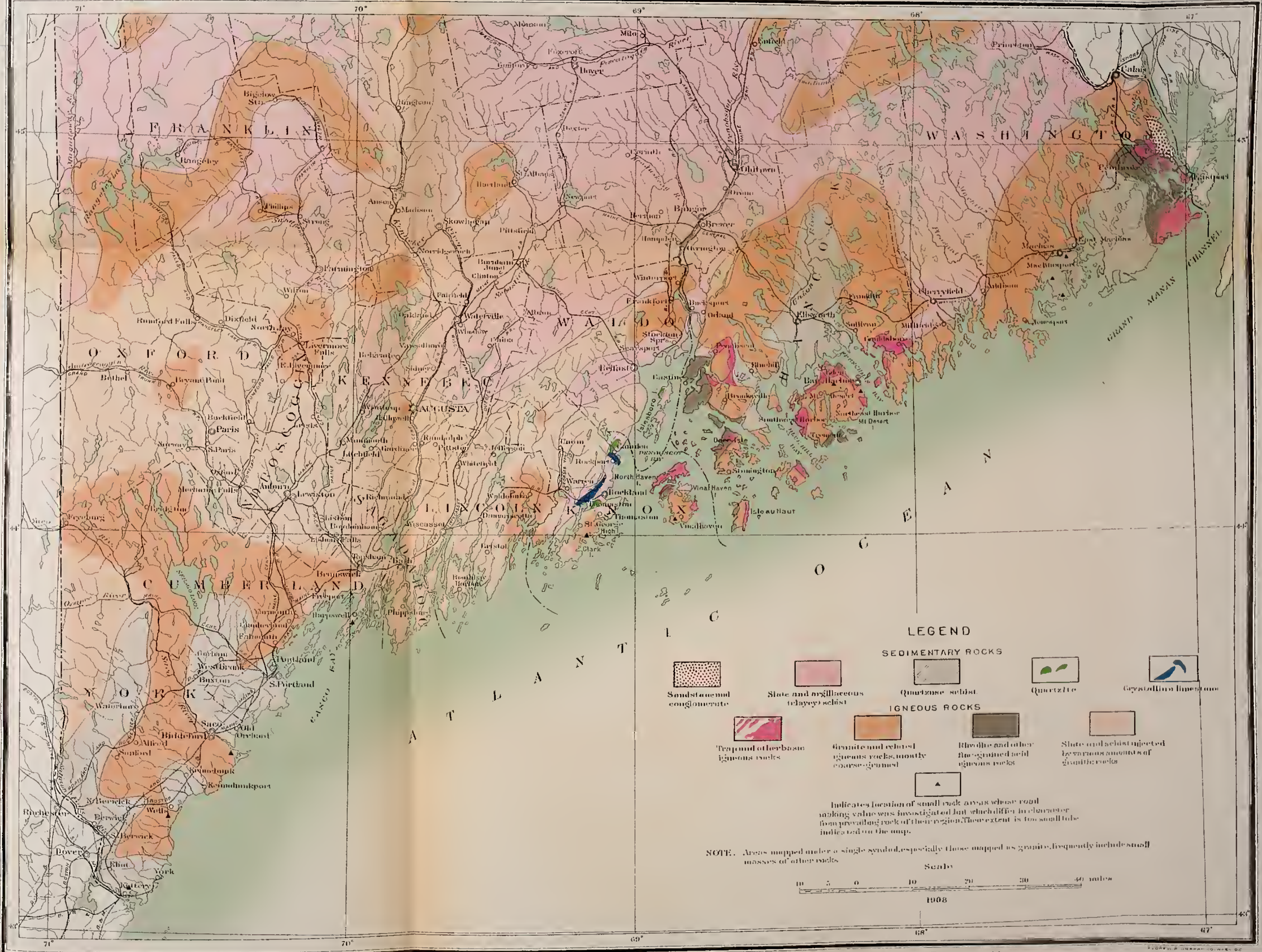

DISTRIBUTION OF PRINCIPAL KINDS OF HARD ROCKS AVAILABLE FOR ROAD CONSTRUCTION IN SOUTHERN AND EASTERN MAINE

sedimentary rocks. The basic dikes range in age from Cambrian to Devonian and possibly even later.

In the Pleistocene period immediately preceding the present period of geologic history the whole State was occupied by a sheet of glacial ice. During the melting of this ice and the consequent northward recession of the glacial border were laid down most of the extensive deposits of gravel which form the principal present source of road material in the State.

METHODS OF SAMPLING AND TESTING.

SAMPLING.

The samples for testing were collected according to the specifications issued by the Office of Public Roads of the U. S. Department of Agriculture. Each sample consisted of fragments which would pass through a 3-inch but not through a 1½-inch screen, except one piece, which measured approximately 4 by 6 inches on one face and was about 3 inches thick. The whole sample weighed not less than 30 pounds and was usually selected from the freshest rock obtainable. In addition, a hand specimen illustrative of each sample tested was collected for deposit with the State survey commission of Maine and another for deposit in the United States National Museum at Washington. By special request additional samples from many of the localities studied were collected for deposit in the office of the State highway commissioner at Augusta.

PHYSICAL TESTS.

The following brief summary of the physical tests made upon the samples by the Office of Public Roads will contribute to a proper understanding of Table 1:

Specific gravity.—The specific gravity of a rock is the ratio between its weight in air and the weight of an equal volume of pure water. It is determined by weighing a piece of the rock in air, suspending it in water, and reweighing it while submerged. By dividing the weight in air by the loss of weight in water we obtain the specific gravity. This factor has a practical value, since, broadly speaking, the heavier rocks are better adapted to road making than those of low specific gravity. Heavy rocks when crushed or pulverized under traffic are also less easily carried away by the action of wind and water than those of lower specific gravity.

Weight per cubic foot.—The weight in pounds per cubic foot is obtained by multiplying the specific gravity by 62.4, the weight of a cubic foot of water.

Absorption of water.—This test gives the number of pounds of water absorbed by a cubic foot of the rock in ninety-six hours. It is determined by obtaining (*a*) the weight of the piece of rock in

air, (*b*) its weight in water immediately after submersion, and (*c*) its weight in water after ninety-six hours' submersion. The number of pounds of water absorbed by a cubic foot of rock equals $\frac{c-b}{a-b} \times 62.4$. This factor has an especial bearing on the effects of frost upon roadbeds and is useful when rock is purchased in quantity.

Percentage of wear.—This represents the percentage of material under 0.16 cm. ($\frac{1}{16}$ inch) in size, worn from 5 kilograms of a sample made up of fragments ranging in size from 1.5 to 3 inches in their greatest diameters. The material is abraded in a revolving cast-iron cylinder mounted diagonally on a shaft and rotated for five hours at a rate of 2,000 revolutions per hour.

French coefficient of wear.—This coefficient expresses in different terms the results of the abrasive test just described. It is represented by the formula $\frac{400}{w}$ in which w represents the weight in grams of the detritus of the abrasion test, under 0.16 cm. in size, obtained per kilogram of rock used.

Hardness.—This is determined by grinding the sample with sand of a standard size and quality. The measure of hardness is inversely proportional to the loss of weight due to the grinding.

Toughness.—The toughness is understood to mean the power possessed by material to resist fracture under impact. The apparatus used in its determination consists of an impact machine fitted with a plunger whose lower surface is spherical, so that the blow is delivered at but one point on the test piece. The weight of the hammer is 2 kilograms and of the plunger 1 kilogram. The test is accomplished by placing a cylinder of the rock 25 by 25 mm. in size under the plunger and allowing the hammer to fall upon it from a distance of 1 cm. for the first blow, each succeeding blow being increased by a distance of 1 cm. until the rock gives way. The number of blows necessary to produce such a result is given as the toughness value. Even rocks possessed of considerable hardness may be so brittle or so incoherent that they crumble under the continuous pounding of traffic. Toughness is therefore a factor of great importance to the road builder.

Cementing or binding power.—This is the property possessed by rock dust or other finely divided material found in nature to act as a cement or binder on the coarser fragments in the road. Its importance is well set forth in the following quotation:[a]

> This property varies enormously, not only with different kinds of rocks but also with those which are practically identical in classification and chemical composition. The absence of cementing power is so pronounced in some varieties of rock that they

[a] U. S. Dept. Agriculture, Bureau of Chemistry Bul. 79, p. 9.

Maine specimen number	ient of		Hardness.			Toughness.			Cementing value.		
	sts of many nples.		Test of Maine sample.	Tests of many samples.		Test of Maine sample.	Tests of many samples.		Test of Maine sample.	Tests of many samples.	
	x.	Min.		Max.	Min.		Max.	Min.		Max.	Min.
1			18.4			30			82		
2			16.2			11			500		
3			18.2			12			28		
4			16.9			11			58		
5			17.9			27			82		
6			18.2			20			59		
	.5	**6.4**		**19.2**	**12.8**		**54**	**4**		**500+**	**2**
7			17.6			12			37		
8			16.5			15			33		
9			17.5			17			135		
10			17.8			12			48		
11			17.8			11			325		
	.8	**7.5**		**18.7**	**17.0**		**22**	**10**		**82**	**7**
12			18.0			7			106		
13			18.1			9			201		
	.0	**4.1**		**19.7**	**15.3**		**42**	**6**		**500+**	**10**
14			18.7			9			27		
15			(a)			(a)			16		
	.0	**2.7**		**19.2**	**13.6**		**31**	**4**		**158**	**3**
16			18.8			8			57		
	.0	**3.9**		**19.0**	**9.0**		**20**	**2**		**110**	**1**
17									19		
18			10.8			7			26		
	.6	**4.7**		**18.9**	**.9**		**34**	**3**		**232**	**7**
19			18.8			11			25		
20			16.5			18			47		
21			18.5			53			31		
22			17.7			14			48		
23									17		
	.4	**5.8**		**18.9**	**1.1**		**40**	**5**		**500+**	**7**
24			18.8			20			20		
25			18.8			9			17		
	.5	**5.3**		**19.7**	**16.5**		**30**	**5**		**45**	**0**
26			10.5			5			85		
	.5	**2.9**		**15.9**	**7.1**		**9**	**3**		**85**	**27**
	.0	**3.8**									
										500+	**5**

TABLE 1.—*Results of tests of road materials from Maine compared with results of many tests of similar materials from various parts of the United States made by the Office of Public Roads, corrected to January 1, 1908.*

Maine specimen numbers.	Name.	Locality.	Number of samples tested by Office of Public Roads.	Specific gravity.				Weight, pounds per cubic foot.				Water absorbed, pounds per cubic foot.			Percentage of wear.			French coefficient of wear.			Hardness.			Toughness.			Cementing value.		
				Test of Maine sample.	Tests of many samples.			Test of Maine sample.	Tests of many samples.			Test of Maine sample.	Tests of many samples.		Test of Maine sample.	Tests of many samples.		Test of Maine sample.	Tests of many samples.		Test of Maine sample.	Tests of many samples.		Test of Maine sample.	Tests of many samples.		Test of Maine sample.	Tests of many samples.	
					Max.	Min.	Average.		Max.	Min.	Average.		Max.	Min.		Max.	Min.		Max.	Min.		Max.	Min.		Max.	Min.		Max.	Min.
1	Diabase (altered)	Harpswell		3.00				187				0.37			2.1			18.9			18.4			30			82		
2	Diabase porphyry (altered)	Hills Beach		2.95				184				.42			2.6			15.4			16.2			11			500		
3	Olivine-diabase (fresh)	Vinal Haven		3.00				187				.33			2.3			17.4			18.2			12			28		
4	Diabase (altered)	Machias		2.90				181				.22			2.8			14.5			16.9			11			58		
5	Diabase (altered)	Black Head		2.90				181				.50			1.6			24.7			17.9			25			82		
6	Diabase (altered)	Eastport		2.85				178				.67			2.0			20.0			18.2			20			50		
	Diabase		124		3.20	2.60	2.95		200	162	181		2.73	0.03		6.3	1.2		34.5	6.1		19.2	12.8		54	1		500+	2
7	Greenstone (altered)	North Haven		2.95				184				.41			2.7			15.0			17.6			12			37		
8	Greenstone (altered)	South Brooksville		2.95				184				.22			2.1			19.4			16.5			15			33		
9	Gabbro-diabase	Wells Beach		2.95				184				.53			2.0			20.4			17.5			17			135		
10	Gabbro	Longeove		3.00				187				.28			2.8			14.3			17.8			12			48		
11	Gabbro	Kittery		2.85				178				1.03			3.2			12.4			17.8			11			325		
	Gabbro		19		3.65	2.80	3.05		228	175	190		.97	.01		5.4	1.3		30.8	7.5		18.7	17.0		22	10		82	7
12	Fragmental andesite	North Haven		2.70				168				.50			3.2			12.6			18.0			7			106		
13	Altered rhyolite	South Brooksville		2.80				175				.77			3.3			12.2			18.1			9			201		
	Rhyolite		21		2.90	2.15	2.60		181	134	162		5.87	.03		9.7	1.7		23.0	1.1		19.7	15.3		42	6		500+	10
14	Granite	Hallowell		2.55				159				1.72			3.1			12.7			18.7			9			27		
15	Granite	North Jay		2.65				165				.39			2.3			17.9			(a)			(a)			16		
	Granite		106		3.00	2.00	2.65		187	125	165		2.77	.04		14.8	4.1		37.0	2.7		19.2	13.6		34	4		158	3
16	Granite-gneiss	Woolwich		2.85				178				.37			4.1			9.9			18.8			8			57		
	Gneiss		61		3.20	2.60	2.75		200	162	172		1.21	.08		10.4	1.7		23.0	3.9		19.0	9.0		20	2		110	1
17	Pegmatite	Topsham		2.65				165				.43			10.7			3.7									19		
18	Mica-schist	Standish		2.75				172				.39			4.0			10.0			10.8			7			26		
	Schist		60		3.20	2.65	2.90		200	165	181		1.35	.06		8.6	1.8		22.6	4.7		18.9	.9		34	3		232	7
19	Quartz-schist	Portsmouth		2.75				172				.14			2.7			14.8			18.8			11			25		
20	Quartz-schist	Kittery		2.75				172				.49			2.3			17.5			16.5			18			47		
21	Quartz-schist	Saco		2.80				175				.27			2.5			15.7			18.5			33			31		
22	Quartz-schist	Portland		2.75				172				.27			2.6			15.4			17.7			14			48		
23	Slate	Bangor		2.70				168				.07															17		
	Slate		30		3.35	2.65	2.80		209	165	175		2.10	.15		6.9	1.6		21.1	5.8		18.9	1.1		10	5		500+	7
24	Feldspathic quartzite	Rockland		2.65				165				.54			2.6			15.2			18.8			20			20		
25	Feldspathic quartzite	Camden		2.70				168				.16			2.7			14.7			18.8			9			17		
	Quartzite		53		3.10	2.50	2.70		193	156	168		1.53	.05		7.6	1.6		21.5	5.3		19.7	16.5		30	5		15	0
26	Marble	Rockland		2.70				168				.36			5.6			7.1			10.5			5			85		
	Marble		9		2.85	2.70	2.75		178	168	172		1.04	.16		14.0	3.8		10.5	2.9		15.9	7.1		9	3		85	27
	Field stone		89													10.3	2.1		19.0	3.8								500+	5
	Gravel		75																										

a Not tested.

can never be made to compact with the road roller or under traffic. As the binder surface of a macadam or gravel road is most exposed to the action of wind and rain, as well as the wear and tear of traffic, it can be seen that the presence of this property is most essential to good results. Further than this, the hardness and toughness of the binder surface, more than of the rock itself, constitutes the hardness and toughness of the road, for if a load be sufficient to destroy the bond of cementation of the upper surface of a road the stones below are soon loosened and forced out of place. The impervious shell obtained by the use of a rock of high cementing value gives the greatest protection to the foundation of a road. Moreover, it is a matter of common observation that a good surface which binds well is less dusty and less muddy, while the advantage from the standpoint of economy is very great, as it is only the loose, unbound material which is ordinarily carried away by wind and water.

The cementing test is made as follows: A portion of the rock is ground so as to pass through a 0.25 mm. sieve, mixed with water into a stiff dough, allowed to "season" twenty-four hours, then molded into cylinders 25 by 25 mm. in size. These are dried in air twelve hours, in a steam bath twelve hours, and then tested. An impact machine is used, allowing a hammer of 1 kg. weight to fall 1 cm. upon the cylinder. The number of blows required to crush the cylinder is given as the cementing value. When the number of blows required to fracture the cylinder lies between 100 and 500 the cementing value is rated as "excellent;" between 75 and 100 as "very good;" between 25 and 75 as "good;" and below 25 as "fair" or "poor."

MICROSCOPIC STUDIES.

Thin sections of the rocks which were submitted to the physical tests were examined under the microscope both by the Office of Public Roads and by Mr. Leighton, and the results are given in some detail in the locality descriptions. Such studies are of the utmost importance, since the road-making qualities of the rock are largely dependent upon the arrangement, character, and size both of the original and secondary mineral constituents, while the cementing value, and to some extent the wearing qualities, are influenced in an important manner by the character and the amount of the secondary or alteration minerals present. All of these characteristics are readily determined by microscopic study. Such studies furnish therefore a useful supplement to the physical tests and may frequently afford an explanation of their results.

VARIETIES OF MATERIALS AVAILABLE FOR ROAD CONSTRUCTION IN MAINE.

The materials available for road construction in Maine are the hard rocks of the State and the gravels, sands, and clays derived from their disintegration or decay. The hard rocks are present in great variety, as is shown by Plate I, upon which is platted the distribution, so far as is now known, of the different rock types. The distribution of the

surface deposits of gravel, sand, etc., is in most parts of the State too imperfectly known and too irregular to be indicated on a map, but a number of the more important occurrences of these materials will be described in the text.

TRAP AND OTHER FINE-GRAINED BASIC IGNEOUS ROCKS.

The name trap is a comprehensive term properly applied to dark-colored basic igneous rocks usually of fine grain. As a trade name it has frequently been applied to other rocks of good road-making quality, such as dark-colored quartzitic schists, and some acid volcanic rocks. Such usage is incorrect and in this report the term is used in its restricted sense. In Maine the principal rocks which may be classed under this head are diabases, though some fine-grained diorites, basalts, and dark-colored trachites are also included. Most diabases are made up essentially of the minerals feldspar and pyroxene, with occasionally small amounts of black mica and other minerals; and diorites differ from them mineralogically mainly in the fact that the mineral hornblende is present in place of part or all of the pyroxene. Most diabases and many diorites are characterized by a peculiar interlocking of the mineral grains, due to the fact that the feldspar occurs in elongate tabular crystals oriented in every conceivable direction. This texture is illustrated in Plate II.

The first six samples, tests of which are shown in Table 1, were rocks belonging to this class. With the results are inserted in bold-faced type, for comparison, the values obtained by averaging the results of a considerable number of physical tests made on similar rocks by the Office of Public Roads.

A study of the results of these tests shows that fresh rocks of the trappean type are characterized by hardness, by a high degree of toughness, by a low percentage of wear, and by good cementing values. Rocks of this general type differ considerably among themselves in road-making value, but almost all of them are superior to the best rocks of other types. The tests also show that a slight amount of alteration in such rocks, while diminishing somewhat their hardness and toughness and increasing the percentage of wear, may nevertheless increase their road-making value because of the development of secondary minerals and the consequent increase in their cementing value. The small amounts of secondary minerals necessary to produce this result may be present, however, without producing any appreciable change in the external appearance of the rock, and varieties which appear to the unaided eye to be notably weathered should be avoided.

The high degree of toughness exhibited by these rocks is due in a large measure to their interlocking texture, though the toughness of the minerals pyroxene and especially hornblende, of which they

contain large amounts, doubtless contributes also to this result. Their good wearing quality is due in part to the fineness of the grain, the texture, and the hardness of the minerals, and also to the fact that the constituent minerals differ only slightly from each other in hardness, a feature tending to diminish differential wear.

In southern and eastern Maine trappean rocks are present in abundance only in the Penobscot Bay region and in the southeastern part of Washington County, though occurring as occasional small dikes in nearly all parts of the region under discussion. The traps of the Penobscot Bay region are for the most part surface volcanics belonging to the North Haven greenstone, but they include also the diabase ("black granite") associated with the granites on the island of Vinal Haven and in the vicinity of St. George (Knox County). These rocks are described and mapped in detail in the Penobscot Bay [a] and Rockland [b] folios and are discussed more fully in the locality descriptions for Knox County. Tests Nos. 3, 7, and 8 of Table 1 show much of this material to be of excellent road-making quality and many of the deposits are favorably located for cheap quarrying and ready shipment by water.

The best and most extensive occurrences of trappean rocks known in the State are in the extreme eastern portion between Machias and Eastport. These rocks are mostly sills and surface flows of diabase, and are frequently very fresh. Especially in the vicinity of Eastport they are so situated that the rock can be cheaply quarried and loaded directly into vessels for shipment by water to other parts of the New England coast. Tests of specimens 4, 5, and 6 of Table 1 show their excellent road-making qualities.

The trappean rocks observed in other parts of the State, especially in York and Cumberland counties, occur mainly as dikes from a foot or so to 30 or 40 feet wide cutting other rocks. They may be of value for local use, but their amount is in most cases too limited to warrant development on a large scale or shipment to a distance. The more important occurrences are mentioned in the detailed locality descriptions. As yet the trap rocks of Maine have been utilized to a very slight extent in road construction.

RHYOLITE AND OTHER FINE-GRAINED ACID IGNEOUS ROCKS.

Under this heading are included rhyolites, dacites, and acid andesites, all finely-granular or glassy igneous rocks, whose principal constituents are feldspar or feldspar and quartz, with relatively small amounts of the dark-colored, basic minerals which particularly characterize the trap rocks. They are surface volcanic rocks occurring as tuffs, flows, sills, and dikes.

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[a] U. S. Geol. Survey, Geologic Atlas U. S., folio No. 149, 1907.

[b] Loc. cit. (see page 8).

A study of the tests made upon materials belonging to this class—Nos. 12 and 13 of Table 1—shows that their percentage of wear is moderately low, though higher than for most trap rocks. Their hardness is nearly the same as in the traps, but their toughness is notably inferior. The latter difference is probably due to the absence in most rhyolites, dacites, etc., of the interlocking structure among the mineral grains, so characteristic of many traps. Their cementing value is about the same as in the traps and related rocks. In general they are of excellent quality for the building of roads for light traffic.

It is perhaps unfortunate from the standpoint of road-building that the rocks belonging to this type are mainly confined to the same districts which are characterized by an especial abundance of trappean rocks. The latter being superior in road-making qualities would naturally claim first attention in any attempts at extensive exploitation. The rhyolites and related rocks of the Penobscot Bay region are described and mapped in detail in the Penobscot Bay [a] folio. They range from Cambrian to Silurian in age and are described in greater detail in the locality descriptions under Knox and Hancock counties. Other areas occur within the Frenchman's Bay quadrangle and will be mapped and described in detail in the folio of that region now in preparation. Tuffs, flows, and sills of rhyolite are also present in abundance in the Englishman Bay and Cobscook Bay regions, in the eastern part of Washington County. Some of these are described in the locality descriptions under Washington County, and many of them will be mapped and described in detail in the folio of this region now in preparation. Many of these deposits are favorably situated for water transportation of the rock. North of the region dealt with in this report, acid volcanic rocks are known to occur in the Mount Kineo region, near Moosehead Lake, and in the region between Ashland and Presque Isle, in Aroostook County.

GABBRO AND OTHER COARSE-GRAINED BASIC IGNEOUS ROCKS.

Under this head are included gabbros, peridotites, and some of the coarser-grained diorites, all of them heavy rocks of dark color and moderately coarse grain. They belong for the most part to the class of plutonic rocks, or those which have solidified at some little distance beneath the surface, rather than to the class of surface volcanics which was represented by the rhyolites and many of the trap rocks. The name trap has frequently been applied to rocks of this type as well as to the fine-grained basic rocks.

Tests made upon Maine rocks belonging to this class appear in Table 1 under numbers 9, 10, and 11. These and other tests on

[a] Loc. cit. (see page 13).

similar rocks show that in general their wearing qualities are not so good as those of the two classes of finer-grained rocks previously described, but are about on a par with those of most granites. Their hardness and cementing value are about equal to those of the traps but they are somewhat inferior to them in toughness. The latter deficiency is due mainly to the fact that their texture is usually granular rather than interlocking as in the case of many trappean rocks. The presence of small amounts of secondary minerals increases their cementing value. In general, these rocks may be regarded as intermediate in road-making value between the true traps and the granites.

Rocks of the coarse-grained basic varieties have a wide distribution in Maine. In York and Cumberland counties they occur as numerous dikes and small stocks intrusive in the altered sedimentary rocks. Here they may prove of value for local road use, though seldom of sufficient size to support extensive quarry operations. Further east considerable deposits of rather coarse quartz-diorite occur at Round Pond, in Lincoln County, and at Long Cove, in Knox County. In the Penobscot Bay region, as described in detail in the Penobscot Bay folio, gabbroid rocks are abundant in the vicinity of Brooksville and Penobscot and on the east side of Isle au Haut. The diabase porphyry ("black granite") quarried at Hermon Hill, near Bangor, and the gabbro quarried near Addison, in Washington County, are other possible sources of road material of this class. In the extreme eastern part of Washington County rocks of this class are perhaps more abundant than anywhere else in the State. Here they are gabbros and coarse diorites occurring as stocks, sills, and dikes in the sedimentary or surface volcanic rocks. A large part of the area south of Lubec is occupied by rocks of this character. All of these occurrences are referred to at greater length in the detailed locality descriptions. This class of rocks has up to the present time been little used on the roads of the State, but may prove valuable for local use in many districts where trap rock is not available.

GRANITES AND OTHER COARSE-GRAINED ACID IGNEOUS ROCKS.

Under this head are included true granites of various compositions and textures and the pegmatites. Granites may be defined as fine to coarse-grained igneous rocks made up principally of quartz, potash feldspar, and mica. The latter may be either of the light-colored variety (muscovite) or the dark-colored (biotite), and in some instances both are present. Hornblende is frequently present with or in place of mica. The texture of granites is in general granular—that is, the mineral grains are more or less equi-dimensional, as shown in Plate III. The interlocking structure characteristic of

many of the traps is absent. As far as their mineral make-up is concerned, the pegmatites may be regarded as granites of very irregular and often extremely coarse texture.

The results of tests made on granites—Nos. 14, 15, and 16 of Table 1—show that in general they possess a high degree of hardness but low toughness and poor cementing value. Their percentage of wear is about the same as for the coarse-grained basic igneous rocks, gabbros, etc. Their low toughness appears to be due largely to the fact that their texture is granular rather than interlocking and to the abundance in most of them of the platy mineral mica. In general, the finer-grained varieties possess greater toughness than those which are coarser. Their low cementing value is probably explained, in part at least, by the scarcity of those secondary minerals which develop by decomposition from the basic, dark-colored minerals. In general, the use of granites alone, especially the coarser granites, in road construction is to be avoided when gravels of good quality or rocks belonging to any of the three classes previously described are available. With a top dressing of some rock such as trap, possessing greater toughness and cementing value, they may, however, be used to good advantage.

Pegmatite has been used to a slight extent on roads, most of them built by private parties in the vicinity of feldspar quarries. Being the material most easily and cheaply obtained, its use is justified upon such private roads, though better results for the heavy traffic involved could be obtained with other materials. A test of pegmatite—No. 17, Table 1—from the feldspar quarries in Topsham, Sagadahoc County, shows an extremely high percentage of wear, while its cementing value, as in the case of the granites, is low. Its use on public roads should be avoided.

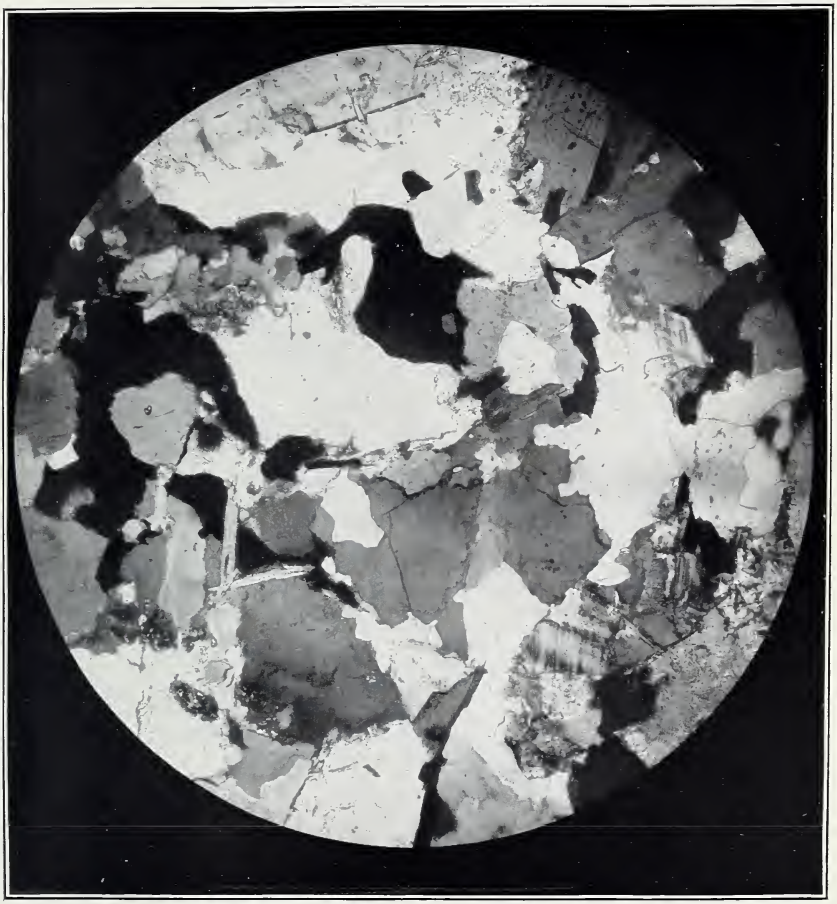
SLATES AND SCHISTS INJECTED BY GRANITIC ROCKS.

Especially in the southern and southwestern parts of Maine there are considerable areas (see Pl. I) from which large continuous masses of granite are absent, but in which the prevailing sedimentary schists have been intruded in the most intimate manner by dike-like or irregular masses of fine granite and pegmatite, and in many places have been given a gneissic or coarsely-banded texture through a layer-by-layer injection of granitic material.

A sample of the injection gneiss from Woolwich, across the river from Bath, may be taken as typical of most of this material. This rock is described in more detail in the locality descriptions of Sagadahoc County. The test of specimen No. 16, Table 1, shows it to be nearly on a par in road-making value with the average biotite granite. It is of good hardness, only medium resistance to wear, low toughness, and good cementing value. Because of their schistose structure

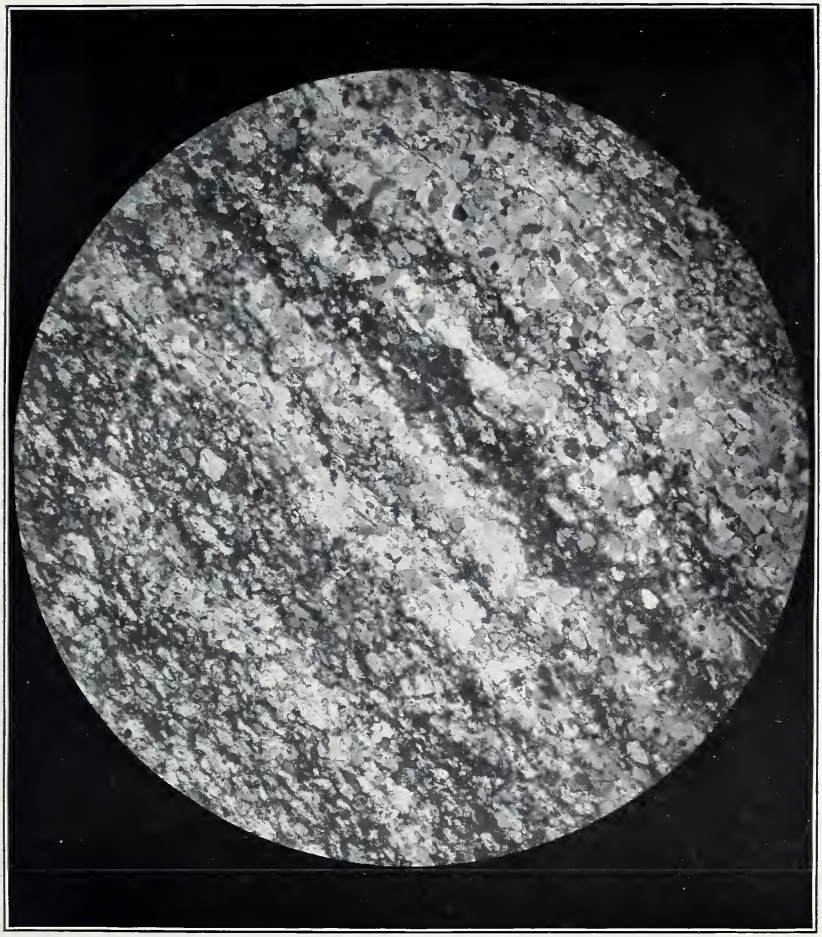
TYPICAL DIABASE (TRAP) FROM DIKE ON BRADBURY ISLAND, HANCOCK COUNTY, MAINE.

Magnified about 30 diameters, polarized light. Shows the interlocking texture which contributes largely to the toughness and resistance to wear exhibited by rocks of this type. White lath-shaped crystals are plagioclase feldspar. Dark areas are mainly pyroxene (augite).



GRANITE FROM BOOTH BAY HARBOR, MAINE.

Magnified about 30 diameters, polarized light. Shows characteristic equi-granular texture, an important factor in the rather low toughness and low resistance to wear exhibited by these rocks. The white and light-gray areas are mostly hornblende.



ELLSWORTH SCHIST FROM BLUE HILL, HANCOCK COUNTY, MAINE.

Magnified about 30 diameters, polarized light. Shows the schistose or foliated structure which causes the rock to split up quickly under traffic. The darker bands contain an abundance of green chlorite; the lighter bands are mainly quartz.

and the large percentage of mica present, these rocks are on the whole inferior in road-making value to the granites and the other classes of rocks thus far described, with the exception of pegmatite. Their use for road material is not recommended unless used in connection with other rock of better wearing quality and higher cementing value.

SLATES AND ARGILLACEOUS SCHISTS.

Almost the whole of the northern half of the area described in this report is occupied by rocks, originally clay and muds but now consolidated and metamorphosed to form slates and argillaceous schists. For the most part they are gray to purplish rocks which split readily along planes of cleavage or of schistosity and are frequently rich in micaceous minerals.

Tests of materials of this type—Nos. 18 and 23 of Table 1—show in general a moderately high percentage of wear, low hardness and toughness, and only a fair cementing value. The foliated character of these rocks causing them to split into thin chips is the most serious drawback to their use as road material. Their poor wearing qualities cause the more clayey varieties to grind up under traffic and make the roads dusty when dry and extremely muddy when wet. This has proven to be the case with crushed slates on many of the public roads near Bangor. Such materials are not only inferior to any of the classes of rocks thus far discussed but are also inferior to a good quality of gravel, and their use should be entirely avoided.

QUARTZOSE SCHISTS.

The areas occupied by the more quartzose phases of the metamorphic schists are rather imperfectly known and are rather irregular in their form and indefinite in their boundaries, for they grade without break into areas of more argillaceous schists and slate.

In the extreme southern part of the State, in York and Cumberland counties, the schists appear to be largely of a quartzitic character, though alternating here and there with bands and lenses of a more argillaceous type. In the extreme eastern part of Washington County, from Machias to West Quoddy Head and Lubec, are also considerable areas of quartzitic slates associated with varying amounts of volcanic and intrusive igneous rocks. The Ellsworth schists of Bluehill, Ellsworth, and a part of the region to the northward are also mapped under the same symbol, though they differ both in age and character from the schists of the other areas. Geologically they are the oldest known rocks of the State and are probably Cambrian or pre-Cambrian. They are not generally quartzose like the schists already described, but are argillaceous. They have, however, been intensely crumpled and permeated by large amounts of white quartz which penetrates the schist as narrow veinlets, usually parallel to the

schistosity but sometimes crossing it. These rocks may be properly mapped therefore as quartzose schists. Their character is more fully described in the Penobscot Bay folio and in the locality descriptions of Hancock County in this report. Plate IV shows their foliated character.

The tests on the quartzitic schists—Nos. 19, 20, 21, and 22 of Table 1—show that they have a low percentage of wear, good hardness, fair toughness, and good cementing value. They have been used with excellent results on the roads of Portsmouth, N. H., Saco and some other parts of southern Maine. In these portions of Maine trap rock is present only as small scattered dikes and the occurrence of the quartzitic schists is extremely fortunate. Whenever it is possible to include in the quarry one or more of the basic dikes which cut the schists at frequent intervals, the admixture of such rock will appreciably enhance the value of the materials.

Quartz-bearing schists of the type represented by the Ellsworth schist have been used on the roads of Ellsworth and are now quarried and crushed for this purpose a few miles north of this city. While superior in road-making quality to the slates and argillaceous schists which are not quartz-injected, they are much inferior to the quartzitic schists already described and to a good quality of gravel. Their use, except in conjunction with rock of better quality, should be avoided.

QUARTZITE AND QUARTZITE CONGLOMERATE.

Quartzites and quartzite conglomerates, which may be defined as thoroughly consolidated and cemented sandstones and conglomerates, occupy only very limited areas in the region under discussion. The majority of these lie within the area mapped in the Rockland[a] folio and are described in detail therein. Small areas occurring on North Islesboro are mapped and described in the Penobscot Bay[b] folio. These occurrences are also described in the detailed locality descriptions in this report.

The results of the tests on Maine rocks of this kind—Nos. 24 and 25 of Table 1—and on similar rocks elsewhere, show that they possess fairly good wearing properties and good toughness and hardness, but a low cementing value. The latter factor is of such vital importance that the use of quartzite alone in road construction can not be recommended. With a top dressing, however, of rocks of high cementing value, like limestone or trap, excellent roads might be constructed. Both of the latter types of rock occur abundantly near the quartzite areas. No quartzite is known to have been used in Maine to any extent as road material.

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[a] Loc. cit. (see page 8). [b] Loc. cit. (see page 13).

LIMESTONE.

The limestones of the part of Maine dealt with in this report occur almost entirely on Islesboro and in the vicinity of Rockland, though small areas are found near Lubec, in Washington County, and in other localities. The principal areas are described and mapped in detail in the Rockland and Penobscot Bay folios. The limestone of these larger areas has been completely recrystallized through regional metamorphism and is now virtually a marble. It varies in color from pure white to nearly black, light grays and blue grays being the prevailing tints. There are corresponding variations in purity and hardness.

The tests on the limestone from the Rockland formation—No. 26 of Table 1—and tests on limestones from other parts of the United States show, in general, low toughness, low hardness, and a high percentage of wear, but good cementing value. When used alone, they tend to crumble and form dusty and muddy roads, but they may yield excellent results when used as a top dressing with rocks of greater hardness and better wearing properties. So far as known they have not been extensively used on any of the roads of the State.

SANDSTONE AND CONGLOMERATE.

Within the area treated in this report these rocks are known to occur only in the eastern part of Washington County, principally in the vicinity of Perry. These conglomerates are but little superior to gravels as a material for use on roads and would be much more costly to obtain. They are associated, moreover, with abundant supplies of the vastly superior road materials—trap and massive rhyolite.

GRAVEL.

Deposits of gravel, for the most part deposited by waters flowing from the melting glaciers, though in part formed by marine action, are exceedingly abundant in nearly all parts of the State, and at present they are the principal type of material used in improving the roads. They may be divided into two classes, the glacial gravels and the present beach gravels.

The glacial gravels, which are the class most extensively used on the roads, show many variations in character. These variations include differences in the character and relative abundance of the kinds of rocks making up the gravel, in coarseness, and in the assortment of the materials (i. e., the extent to which the coarser portions are separated from the finer). The differences in coarseness and in degree of assortment of the materials are dependent upon the conditions of deposition, especially upon the swiftness and volume of the depositing waters and the length of time during which the mate-

rials are subjected to water action. The types of rocks present in the gravels, as in other phases of the drift deposits, are dependent in composition upon the character of the rocks in the region from which these have been derived. Since the general ice movement in this region was from the northwest, the materials of the glacial drift were in a general way derived from districts lying to the northwest of the localities in which they are now found. This relationship applies less closely, however, to those phases of the drift which were transported in part by water than to those transported by ice alone, and is not closely applicable to gravels deposited after the ice had retreated some distance back from the coast, when many of the streams flowing from its margin had assumed courses more southerly than the general trend of the ice movement. Many of the gravel deposits have, moreover, been collected from large drainage basins frequently characterized by a great variety of rock types. It is impossible, therefore, in most cases to trace an exact correspondence between the character of the gravels and the types of rocks present in the region to the northwest of the locality in which they occur, though certain recognized differences may be explained on this basis. As instances of notable variations in the character of the gravels, the pebbles in those used on the roads near Elliot, in York County, are about one-third of quartzitic and argillaceous schists and two-thirds of granitic rocks, while the pebbles in gravels along Sandy River, in Franklin County, are about one-fourth trap rock, one-fourth quartzite, and one-half granitic. Pebbles and gravels along the Kennebec near Augusta are composed of nearly equal parts of soft schist pebbles and pebbles of granite and impure quartzite.

Beach gravels are found along all portions of the coast of Maine, but are not so abundant as along the less rocky shores farther south on the Atlantic coast. They occur principally in small, somewhat protected, coves. Their character is much more closely dependent upon the character of the rocks in their immediate vicinity than is the case with the glacial gravels, since in many cases they have been formed directly by the erosive action of the ocean waves and currents upon the solid rocks of the coast. In some instances, however, they have been formed by the marine erosion of deposits of till or of glacial gravels, and they may then show as much diversity in the character of their materials as do the glacial gravels.

The gravels have a great advantage over other types of road material in that they are easily excavated and require no crushing. They are therefore much cheaper than most hard-rock materials. A second point in their favor is their wide distribution, especially along the river valleys, where the principal manufacturing towns are located. These valleys are also in most cases the lines of railroad traffic, so that the gravels can readily be shipped to a distance.

Their value as road materials, as has already been intimated, is dependent largely on their composition. Other things being equal, those gravels which contain the greatest abundance of pebbles from rocks which in themselves possess good road-making qualities are of greatest value. This is especially noticeable in the case of beach gravels which, along some shores where trap, massive rhyolite, and other rocks of excellent road-making qualities are abundant, are frequently made up almost entirely of these materials. The fragments have in most cases, however, been so rounded by wave action that their binding power is much less than that of crushed stone of similar composition. Many of the glacial gravels also are so clean, well rounded, and well assorted that when spread upon a road and subjected to travel the smooth pebbles slip upon each other and allow the wheels to sink in. In general it may be stated, therefore, that the best gravels for road use are not the clean, well-rounded types, but those less perfectly rounded, and assorted varieties which contain a matrix of clay or sandy clay. Such a matrix serves as a binder for the pebbles and if present in the proper proportions insures a firm, compact roadbed. In some cases, especially in districts where clays are abundant, it may be found desirable to mix with the gravel a certain amount of clay or clayey sand to increase its binding properties.

SAND AND CLAY.

In certain parts of the State there are large areas where the surface materials are principally sand or principally clay. The sandy areas are for the most part plains bordering the larger river valleys, a notable example being afforded by the sand plains in the vicinity of Brunswick. The clays are most abundant on the lowlands bordering the coast, their distribution in the vicinity of Camden, Rockland, and Thomaston being mapped in detail in the Rockland[a] folio. Their distribution in the latter region may be regarded as typical of their occurrence elsewhere along the coast. Over many other areas the surface materials are a mixture of sand and clay.

Practical experience in road construction and the results of experiments conducted by the Office of Public Roads have shown that in sandy areas serviceable roads offering excellent resistance to light travel may be constructed by mixing clay in proper proportion with the sand, and that in clayey regions the same result may be obtained by the reverse process.

It is unnecessary here to discuss in a theoretical way the properties of clays and sands which lead to these results, nor can any definite rules be given in regard to the proportions in which these constituents should be mixed. This proportion will vary with the character

[a] Loc. cit. (see page 8).

of the sand and clay in the particular region under investigation. In general, however, it may be stated that the clay should be present in sufficient amount to occupy completely all of the interspaces between the sand grains, and that the materials can not be satisfactorily mixed in a dry state, but should be mixed and puddled in water. Practical experience has shown that the tendency is to calculate too little rather than too much sand for given amounts of clay. The cost of constructing roads of this type is low as compared with the cost of macadam. For more detailed information on this subject the reader is referred to a recent bulletin of the Department of Agriculture.[a]

LOCALITY DESCRIPTIONS.

ANDROSCOGGIN COUNTY.

The rocks of this county are almost entirely schists injected by rocks of granitic composition, though in the northern part of the county, in the towns of Livermore and East Livermore, there is a considerable area which is wholly granite. No trap dikes of sufficient size to be important as road material were observed in the county. Gravels of excellent quality are abundant, particularly in the valley of the Androscoggin River, and these deposits will probably always constitute the principal local source of road material. Field stone is abundant in the higher portions of the county back from the river valleys and may be crushed and used with good results.

As already stated (pp. 16–17), the schists injected by granitic material form poor material for road construction.

The granite occurring in the northern portion of the county is similar to that quarried at Jay in Franklin County and described on page 25. Physical tests of this granite indicate that it has high resistance to wear and a fair cementing value. No tests of hardness or toughness were made, but in common with most granites its toughness is probably low. Roads constructed of this granite, if carefully laid, will probably give fairly good results for light traffic, especially if a top dressing of trap is applied to increase the cementing value.

CUMBERLAND COUNTY.

The rocks of Cumberland County are mainly granites, except in the southeastern part near Portland and Gorham, and southeast of Sebago Lake, where they are largely quartzitic schists, and in the extreme western part between Fryeburg and Ossipee River, where they are schist injected by granitic rocks. A small area of schist injected by granitic rocks also occupies the eastern townships of this county.

[a] U. S. Dept. Agriculture, Farmers' Bulletin 311.

Brunswick.—The rocks of this town are granites and schists injected by granitic material with occasional intrusive dikes of diabasic igneous rock. Gravels are abundant, particularly along the Kennebec River, and are the materials most extensively used upon the roads. The schists injected by granitic material, though in general ill adapted for road construction, have been quarried to some extent in Brunswick just north of the Harpswell line and used on the Harpswell-Brunswick road. In this locality no gravels of good quality are readily accessible. Another material used on the Harpswell road near Brunswick is a gray mica-schist very soft and fissile, and possessing none of the qualities essential for good road material. Small amounts of pegmatite quarried in Topsham, Sagadahoc County, have been used on the roads of this town. The qualifications of this material may be judged from the test of specimen No. 17 of Table 1, a typical pegmatite from the Topsham quarry. Its characteristics are discussed more fully under the town of Topsham, Sagadahoc County (p. 39). Considerable areas east and southeast of Brunswick are extremely sandy and the roads in this section are consequently very poor. Many of these roads could be greatly improved by mixing with the sand of the roadbed a proper proportion of clay, which can be obtained in abundance in many localities along the neighboring shores.

Cape Elizabeth.—The rocks of this town are largely quartzitic schists associated with small areas which are more micaceous. Intruding the schists are a few small trap dikes. Massive quartzitic schist affords good road material, but the fissile micaceous variety should be avoided.

Freeport.—In the western part of this town are granites and in the eastern part occur schists injected by granitic material. Small trap dikes are abundant, but no large ones were observed, though more careful search may result in their discovery. The granite is the best hard-rock material available but should preferably be used with a top dressing of trap. Gravels are abundant.

Gorham.—Gravels are very abundant in this town but are prevailingly rather fine-grained and sandy. Though probably the best local materials available they are not of first quality for road construction, since they consist largely of granitic material. The hard rocks of the town are largely quartzitic schists similar to those collected and tested from the town of Standish (see pp. 24–25).

Harpswell.—The rocks of the town of Harpswell are mainly schists injected by granitic material. Trap dikes occur here as elsewhere in the county, but are usually small. In one locality, however, on the Brunswick-Harpswell road, 1 mile south of Harpswell Center, occurs a 30 to 40 foot trap dike, almost paralleling the road and rising as a low ridge above its surroundings. The rock is dark gray in color and moderately fine-grained.

Under the microscope it is seen to be a diabase composed principally of altered plagioclase feldspar (52 per cent) and augite (38 per cent) somewhat altered to chlorite (5 per cent). Magnetite and enstatite are present in small amounts as accessory minerals, and secondary biotite and serpentine also occur.

The physical tests of this rock, which is No. 1 of Table 1, show the rock to be hard and tough, with high resistance to wear and very good cementing value. It is well suited for heavy-traffic roads. This material could readily be utilized also as a top dressing for granite roads and would be superior to any of the native materials at present used around Brunswick.

A portion of the main street of Brunswick has been macadamized under the supervision of the State highway commissioner and is one of the best pieces of road in the State. The material used, however, did not come from Maine, but is trap imported from Salem, Mass.

Portland.—The region north of the city of Portland, as far as Presumpscot River, consists of schists highly intruded by granitic material which have little value for road construction. South and west of the city the rocks are largely quartzitic schists with smaller associated areas of more micaceous schists. A sample of the quartzitic schist was collected from a quarry 1½ miles north of the Union Station, Portland. The rock excavated here is crushed and used on the roads in the northern half of Portland. It is a fine-grained quartz-schist, somewhat banded in gray and greenish-brown.

Under the microscope it is seen to be composed essentially of quartz (55 per cent), orthoclase feldspar (6 per cent), small amounts of magnetite, and the secondary minerals zoisite (16 per cent), calcite (7 per cent), chlorite (8 per cent), hornblende (6 per cent), and titanite.

The results of the physical tests of this rock—No. 22 of Table 1—show it to be rather hard and of medium toughness with high resistance to wear and good cementing value. The roads constructed of this rock are hard and smooth, and appear to be very satisfactory in every way. The physical tests and the practical use of this material on the roads show that rock of this type forms the best available material near Portland for road construction. On one face of the quarry is a 3-foot dike of fine-grained diabase which is crushed and mixed with the quartz-schist and which adds somewhat to its binding power and toughness. On many of the roads in the southern part of the city granite from Redstone, N. H., and trap rock from Salem, Mass., have been utilized, but the native quartz-schists should prove nearly if not quite as satisfactory.

Standish.—The western part of this town is composed largely of granitic rocks. The eastern part shows numerous exposures of mica-schists, locally becoming quartzitic. A sample typical of much of the rock in this part of the town was collected from the Portland Reservoir site in the extreme eastern part of Standish between White

Rock and Sebago Lake. Tons of this purplish-gray, fine-grained quartz-mica schist were taken out in excavating for the reservoir and similar material outcrops throughout much of the town of Gorham.

Microscopic examination shows this rock to be finely schistose and composed of dark-colored mica (69 per cent), quartz (30 per cent), and occasional grains of magnetite.

The tests of this rock—No. 18 of Table 1—show that it has low toughness, medium resistance to wear, and good cementing value. Although this material would not stand up well under heavy traffic, it would if well laid, probably give satisfaction under the light traffic to which it would be subjected in the towns of Gorham and Standish, and would be much better than the present roads constructed of sandy granitic gravels.

FRANKLIN COUNTY.

The rocks of this county are largely granites and argillaceous slate and schist with limited areas of schist injected by granitic material; the approximate distribution of these different types of rock is shown upon the map (Pl. I).

The granite occurring in the southern part of the county in the towns of Jay, Chesterville, and Wilton is for the most part light gray medium-grained rock, and may be typified by that occurring at North Jay, where it has been crushed and used for macadamizing the roads.

Under the microscope this rock is seen to consist essentially of quartz (21 per cent), orthoclase and microcline feldspar (60 per cent), and plagioclase feldspar (9 per cent). Accessory and secondary minerals present in small amounts are muscovite, biotite, apatite garnet, and kaolin.

The test of this material—No. 15 of Table 1—shows the rock to possess high resistance to wear and fair cementing value. Its hardness and toughness were not tested, but would doubtless be low, as in other granites. The rock makes a road of fairly good quality for light traffic, but its efficiency could be materially increased by the use of trap rock with good cementing quality as a top dressing.

Field stone is abundant in most parts of the county, and where examined, in the vicinity of Farmington, most of the bowlders were found to be granitic in character, though some of trap occur. This material could be crushed and used on the roads to much better advantage than the slates or the schists injected with granitic material, which are the prevailing bed rocks.

Gravels are abundant in most parts of the county, particularly along Sandy River. In a pit there, in an immense hill of gravel, the pebbles were about one-half granitic, one-fourth trap, and one-fourth quartzite, with sufficient clay matrix to give good cementing power. Roads built of this gravel have a fine appearance and have lasted very well for years.

HANCOCK COUNTY.

The rocks of the towns of Castine, Penobscot, Brooksville, Blue Hill, Sedgwick, Brooklin, Deer Isle, Isle au Haut, and the southern part of Surry, have been mapped and described in detail in the Penobscot Bay[a] folio, and will be discussed by townships below. The rocks of the island of Mount Desert, of Swans Island, Goulds-boro, and of parts of Surry, Trenton, Lemoine, and Sullivan are described in the Frenchmans Bay[b] folio and will also be discussed here in some detail. The rocks of those portions of the county lying north of the areas covered by the Penobscot Bay and Frenchmans Bay folios (i. e., north of latitude 44° 30′) have not been studied in detail, but consist largely of granites and slates, their distribution being shown in a general way on the map (Pl. I). The slates of the northern part of the county are for the most part similar to those in the vicinity of Bangor, and are valueless for road construction. Those occurring in the vicinity of Ellsworth and Ellsworth Falls and probably extending for a considerable distance north of there belong mostly to the formation known as the Ellsworth schist, which is described in the Penobscot Bay folio. As typically exposed near Ellsworth they are greenish-gray, much crumpled and contorted schists injected by small veins and stringers of white quartz.

Under the microscope the principal minerals are seen to be quartz and biotite altering to chlorite, the former occurring in interlocking grains and the latter two in small, irregular plates most abundant along certain parallel layers, thus giving the rock a banded or schistose structure. Accessory minerals are white mica (muscovite) and orthoclase feldspar.

This rock is of somewhat higher quality for road making than the schist of the Bangor region, but because of its schistose character it breaks up quickly under traffic and its use can not be recommended. The most available materials over the northern portion of the county are the gravels, which are abundant and widely distributed.

Blue Hill.—The rocks of this town are granite, diorite, and Ellsworth schist. As already stated, the Ellsworth schist is of poor road-making quality; and the granites, most of them medium to coarse-grained, have low toughness and low cementing value. The diorite occurring in the western part of the township is for the most part rather coarse-grained and therefore of low toughness, though small amounts of finer-grained material occur. Among the hard rocks of the town, it is the one best suited for road building, but the small quantities present and their location back some distance from the coast render them valuable only for local use. The gravels, which are abundant in all parts of the town, are probably the best source of road material.

[a] Loc. cit. (see page 13). [b] In preparation.

Brooklin.—The northern part of the town consists wholly of Ellsworth schist, of poor road-making value. The southern part of the town is composed entirely of medium-grained granite. The best available road material is the gravel.

Brooksville.—The rocks of the eastern part of the town of Brooksville are granites of medium to coarse grain, while the rocks of the whole western portion of the town are acid volcanics (rhyolites and dacites) belonging to the Castine formation. These include both massive flows and tuffs, the former being best suited for road construction. A specimen typical of much of this material, collected at South Brooksville, was fine-grained and purplish-brown in color, with rusty weathered surfaces.

Under the microscope it is seen to be an altered rhyolite composed essentially of quartz (26 per cent) and orthoclase feldspar, the latter largely altered to muscovite. Accessory minerals are biotite, magnetite, and cordierite.

The tests on this rock—No. 13 of Table 1—show it to possess low toughness, medium resistance to wear, and excellent cementing value. It would be a suitable rock for the construction of roads which are to be subjected only to light traffic.

North Haven greenstone occupies the peninsula west of Bucks Harbor, near the village of South Brooksville. A specimen collected here was fine-grained, massive, and light greenish-gray in color.

Under the microscope it is seen to be an altered basic trachite, consisting essentially of plagioclase feldspar, largely chloritized (59 per cent) and hornblende (35 per cent), with small amounts of magnetite and biotite.

Tests of this rock—No. 8 of Table 1—show it to possess medium hardness and toughness, high resistance to wear, and good cementing value. It should make an excellent road material. It is present in large amounts and is so situated that the material can be cheaply shipped by water.

In the northern part of the township there are considerable areas of diorite and gabbro. These rocks are for the most part rather coarse-grained, but enough fine-grained material occurs to furnish abundant supplies for local consumption. Gravels are abundant in all parts of the township.

Castine.—The town of Castine is occupied entirely by the acid volcanics of the Castine formation, whose character has already been described under the town of Brooksville. The more massive types of this material would be excellent for road construction; and there are also large supplies of gravel.

Deer Isle.—The southeastern two-thirds of the island is occupied entirely by medium-grained granite, which is quarried for building purposes principally in the vicinity of Stonington. The northwestern third of the island is occupied by acid volcanics of the Castine

formation with associated areas of serpentine rocks and of North Haven greenstone. The serpentine rock, though rather soft, should possess good cementing value and moderate toughness and would be a moderately good material for road construction. The character of the volcanics of the Castine formation has already been described (p. 27), while the character of the North Haven greenstone is described further on (p. 33). The latter supplies the best hard rock for road construction on the island. Gravel is abundant.

Gouldsboro.—The wide belt of diorite that extends from Sorrento and Sullivan eastwardly through the village of Gouldsboro, as shown on the map (Pl. I) affords, in its finer-grained phases, an abundant supply of an excellent road material of high toughness and good cementing qualities.

The granite of the southern portion of the town, especially from Grindstone Neck northward along the shore, is cut by numerous large and small trap dikes. A number of the larger ones lie near the shore and trend parallel to it for considerable distances. Some of these could be readily quarried for road material.

Isle au Haut.—This island consists largely of granite, with a narrow belt of diorite along the eastern shore and considerable areas of rhyolite in the western part of the island. The road-making qualities of the rhyolite are similar to those described for the andesites of North Haven, Knox County (p. 33). They would furnish an excellent road material. The diorites of the eastern part of the island are for the most part rather coarse-grained and therefore would be of somewhat low toughness. The island has no good harbors; consequently the rock of the island could not be quarried for shipment to a distance. The most available local materials are the gravels.

Lamoine.—The town of Lamoine is occupied largely by Ellsworth schist, which is of poor quality for road construction.

Little Deer Isle.—Little Deer Isle consists wholly of the volcanics of the Castine formation and the North Haven greenstone, with small amounts of serpentine. The last two are abundant and would furnish the best hard-rock material for the roads.

Mount Desert Island.—While the island of Mount Desert is almost entirely made up of biotite and hornblende granites, yet surrounding this granitic core there are considerable areas of diorite of good quality for road construction. Certain finer-grained phases of the biotite granite near the head of Somes Sound might be utilized for constructing roads. The chief present source of road material is found in a belt of rock that fringes the landward side of the island, especially in the neighborhood of Bar Harbor, and is made up of diorites and granites which have intruded and thoroughly brecciated fine-grained flaggy quartzites, frequently giving them greater com-

pactness and resistance than they originally possessed. A mile south of Bar Harbor, on both the east and west sides of Strawberry Hill, quarries for road material for the town of Eden have been established. The quarry face shows the rock to be made up of fragments of quartzite varying in size from a fraction of an inch to several feet across, with stringers of granite or diorite between. The mixture of crushed rock with the hard, sharply angular fragments of quartzite and the softer but tougher igneous rocks with their superior binding power makes a very satisfactory combination of material for the excellent roads in the vicinity of Bar Harbor. Three or 4 miles to the west of Bar Harbor and a couple of miles south of Salisbury Cove, there is another quarry of similar material situated in the same brecciated contact zone.

In addition to these sources of road material, there are found throughout the island innumerable trap dikes. Many of these black diabase dikes are of large size and conveniently located, and would furnish the best of road material.

Acid volcanic rocks, principally rhyolite, occur in the extreme southern portion of the island and would be available for road use, though their utilization could not be recommended in view of the abundance of diorite. Gravels of excellent quality are abundantly scattered over most of the island on the lower levels.

Surry.—The eastern part of the town of Surry is composed mainly of Ellsworth schist, whose poor road-making quality has been mentioned. The western portion is largely granite of medium grain. Gravels should be largely relied upon as the local supply of road material.

Trenton.—The town of Trenton consists largely of Ellsworth schist of poor road-making quality, and the gravels and trap rock from adjacent regions must be relied upon to supply necessary road material.

Islands of Frenchmans and Bluehill bays.—Many of the larger islands in the bays about Mount Desert, such as Ironbound, Bartlett, and Swan, are made up wholly or in part of diorite, which might be made available for road purposes. Many trap dikes occur also on these islands.

KENNEBEC COUNTY.

The whole northern portion of this county is occupied by slates and argillaceous schists of poor road-making quality. A small area around Augusta and Hallowell is occupied by granite, while most of the southern part of the county is underlaid by schist injected by granitic material. Gravels are abundant, particularly along the valley of the Kennebec River and its lower tributaries. Field stone is abundant on the highlands.

Augusta and Hallowell.—The chief material used on the roads of Augusta and Hallowell is the Hallowell granite. This is a moderately fine-grained, gray granite with porphyritic crystals of white feldspar up to about one-half of an inch in diameter.

Under the microscope the rock is seen to be composed of quartz (30 per cent), orthoclase feldspar (45 per cent), and plagioclase feldspar (8 per cent); while there are also 9 per cent mica (muscovite) and small amounts of brown mica (biotite), microcline feldspar, and apatite. The feldspar is somewhat altered with the development of kaolin.

The physical tests of this rock—No. 14 of Table 1—show that the rock is hard but of low toughness. It possesses medium resistance to wear and good cementing value. Macadam roads of this material in Augusta are well built and firm, but because of the low toughness of the granite, causing it to break up under traffic, they are quite dusty in dry weather. If they could be covered with a dressing of a rock of high cementing value, they would be considerably improved. The Augusta-Hallowell granite area is the only one in the county, and its materials could be used to good advantage in many other towns where trap or an abundance of field stone is not available.

On the Manchester road crushed field stone is being used with very encouraging results. The material is largely granitic, but contains about 10 per cent of trap and 10 per cent of quartzitic bowlders. It gives better satisfaction than pure granite. Some of the schists near Augusta—as, for example, those near the King gravel pit—are somewhat quartzitic, but are still too fissile to be of any considerable value as road material.

Gravels around Augusta, according to the information obtained from contractors and the city engineers, are of poor road-making quality. At the King pit, 1 mile north of the post-office, the gravel is too fine-grained and too free from clayey matrix to make a good road material. About half of the pebbles are granite and quartzite while the other half are soft fissile schist. A large deposit of gravel is found at Bond Brook, 2 miles north of the city near the road bridges. It is not well assorted and consists of sand and large rounded pebbles of quartz-schist and granite. Other gravel pits occur near the State house in Augusta and one is located just west of the city of Hallowell.

Waterville.—The rocks around Waterville are entirely slates and argillaceous schists which are wholly unfit for road construction and so far as known have not been so utilized. Crushed Hallowell granite has been used to some extent on the roads here with moderately good results. Field stone is very abundant, especially between Waterville and Fairfield, and could easily be crushed for road use. About

two-thirds of the bowlders are of granitic composition and about one-third basic rocks, such as diabase and diorite. Field stones of this nature frequently make good road materials.

Gravels near Waterville are particularly abundant along the Kennebec and have been extensively used on the roads. The largest deposit now worked lies within the city limits. The pebbles of the gravels are about one-half granite and one-half quartzite with sufficient clay to give good binding qualities. The only drawback to the use of this material is its fineness, which renders it better suited for a top dressing than for the construction of the entire road-bed. Similar gravel is found in the "Plains" southeast of the city. This gravel might be used to good advantage as a binder and top dressing for macadam roads built of crushed granite from Hallowell.

KNOX COUNTY.

Knox County shows unusual variety in its rocks. The portion of the county lying northwest of West Rockport and Warren, and extending southeast from Warren nearly to Friendship, is almost entirely occupied by schist injected by granitic and small amounts of basic rocks. These rocks are similar in their properties to the gneiss from Woolwich in Sagadahoc County (represented by No. 16 of Table 1), and are in general of poor quality for road construction. A belt extending along the coast from the northern border of the county to Rockland and thence southwest to Thomaston and Cushing is underlain by argillaceous slate and schist, also of poor quality for road construction. Considerable areas of quartzite and of limestone occur in the vicinity of Camden, Rockland, and Thomaston.

Granite of various textures is abundant in this county, its distribution being shown in part in Plate I.

Diabase and diorite are abundant in the vicinity of St. George and Long Cove on the mainland and on the islands of Vinal Haven and North Island. On these islands also are considerable areas of massive acid volcanic rocks, rhyolite, and andesite. Small basic dikes are abundant in all portions of the county.

The rocks of the island of Vinal Haven are mapped and described in detail in the Penobscot Bay folio. The hard rocks and gravels of the region between longitude 69° and 69° 15′, and between latitude 44° and 44° 15′ are mapped and described in detail in the Rockland folio.

Appleton.—The town of Appleton is largely occupied by schists injected by granitic material, and residents must rely largely on the gravels as a local source of road material.

Camden.—The western part of this town is occupied by schists injected by granitic rocks with a few small areas which are wholly granite. The injected schists are of poor quality for road construction.

The eastern part of the town is occupied mainly by slates and argillaceous schists with small areas of quartzite, quartzite conglomerate, and limestone. The slates and schists here, as at Bangor, make exceedingly poor road material.

Quartzite and quartzite conglomerate constitute the hill known as "Mount Battie" near Camden and also occur in several small areas near Rockport. The conglomeratic phases of this rock, usually mottled buff to blue-gray in color, consist of well-rounded quartzite pebbles in a quartzite matrix; the nonconglomeratic phases are thoroughly cemented buff to gray quartzite.

The microscope shows this rock to be made up of quartz in intimately interlocking grains (60 per cent) with small associated amounts of white mica (muscovite) and of orthoclase feldspar (both 36 per cent). Accessory minerals present in small amounts are biotite, magnetite, zircon, tourmaline, and calcite.

The tests upon this rock—No. 25 of Table 1—show it to be a hard rock with low toughness, rather high resistance to wear, and only fair cementing value. The position of this quartzite on the flanks of Mount Battie would render quarrying operations very simple, but because of its low toughness and particularly its low cementing value, the material can not be recommended for use alone upon the roads. It could, however, be used to advantage in constructing the foundation of a roadbed, if some material of higher cementing value, such as trap or limestone, were used as the top dressing.

Limestone is not quarried at present in this town, though it underlies certain areas between Camden and Rockport. Its availability for road construction is discussed under the town of Rockport. (pp. 34–35.)

Gravels are present in great abundance, particularly in the eastern portions of this township, their precise distribution and the location of the gravel pits being shown upon the surficial geology sheet of the Rockland folio. A deposit of large extent and good quality for road construction occupies the valley of Megunticook River for 2 miles northwest from Camden.

Cushing.—The hard rocks of the town of Cushing are all schists and slates and phases of these rocks which have been intruded and injected by granitic material. They are uniformly of poor quality for road construction, and gravels must be the materials largely relied upon, although their abundance is not so great as in the towns of Camden, Rockport, and Rockland.

Considerable areas of this town are underlain by marine clays and roads in these sections might be notably improved by mixing sand with clay to form a "sand-clay" road (see pp. 21–22).

Friendship.—The rocks of Friendship are largely granites of various kinds, most of them quite coarse, and small areas of schists in-

jected by granitic rock. All of these hard rocks are of very poor quality for road construction. Gravel is moderately abundant.

Hope.—The rocks of this town are schists injected by granitic material with a few small areas—the largest near South Hope—which are composed entirely of granite. Reliance for local road material must be placed largely upon the gravel deposits, which are fairly abundant. One of the largest of these extends in a southerly direction from the west end of Alford Lake to Crawford Lake. Other large gravel deposits occur southwest of South Hope.

North Haven.—This island is occupied largely by the North Haven greenstone, a formation including several different kinds of basic volcanic rocks, the most abundant of which is diabase. Certain phases, particularly the lava flows, are more compact than others, but even those phases which were originally tufaceous have been so cemented and compacted since their deposition that they would all make fairly satisfactory material for road construction. A specimen collected on Websters Head, of one of the more massive varieties, is fine-grained and greenish-gray in color.

Under the microscope it is seen to be intensely altered, but was probably originally a diabase in composition. Epidote and tremolite are the most abundant minerals and constitute 80 per cent of the rock; augite constitutes 10 per cent and opaline material 9 per cent. Small amounts of magnetite are also present.

The physical test—No. 7 of Table 1—shows the rock to be fairly hard, but not very tough. It has rather a high resistance to wear and good cementing value. If care is taken to locate road-material quarries in the more massive phases of the North Haven greenstone, material could be obtained which would be of excellent value for road construction. It could be easily and cheaply shipped by water to all parts of the coast.

The southern part of the island is occupied largely by volcanic rock, mainly of andesitic composition, which has been named the Thorofare andesite. Much of this formation, especially in the vicinity of North Haven village, is massive, but the specimen tested is a purplish-red fine-grained thoroughly cemented tuff with fragments up to 1 inch long.

Under the microscope it is seen to be made up of fragments of andesites of various kinds and some rhyolite fragments in a groundmass of andesitic composition. The feldspars are much decomposed, and portions of the groundmass originally glassy are completely though finely crystalline. Quartz is present in very minor amounts.

The test made on this rock—No. 12 of Table 1—shows the rock to possess low toughness, medium resistance to wear, and excellent cementing value. It would make a fair road material for light traffic,

but the more massive phases of the andesite would be much superior. Both are inferior to the North Haven greenstone which occupies most of the island.

Rockland.—The rocks of the town of Rockland are almost entirely slate, argillaceous schist, and crystalline limestone, with small amounts of quartzite and siliceous limestone. The slate and schist should not be used on the roads. Limestone is extensively quarried west of Rockland for the manufacture of lime. It is highly crystalline and varies from white to dark blue-gray in color, much of it showing conspicuous banding.

Under the microscope the limestone is seen to be composed largely of calcite of interlocking grains with small amounts of quartz and white mica (muscovite) and a little secondary tremolite. Occasionally other silicate minerals are also developed in it.

The test—No. 26 of Table 1—shows it to be very soft, with low toughness and low resistance to wear, but of good cementing value. Its use alone on the roads can not be recommended, because it grinds up under traffic to a powder which makes the road exceedingly dusty in dry weather and forms a sticky mud in wet weather. It is best suited for use as a binder on roads constructed of such material as quartzite or granite possessing higher resistance to wear, but much lower cementing value.

Quartzite occupies only limited areas in this town, but occurs abundantly farther south in the town of South Thomaston, from which it could be readily carted for use on the streets of Rockland. Its characteristics and road-making qualities are described under the town of South Thomaston (p. 35). A rock intermediate between quartzite and limestone has been quarried and crushed for use on the roads of Rockland in the western part of the city of Rockland. Since this rock combines to a certain extent the superior hardness and resistance of quartzite with the high cementing value of limestone, it should be a fairly satisfactory material for road use, although the quantity available is quite small.

Gravels are very abundant in the region south of Chickawaka Pond, and have been used on the roads to a large extent; their distribution is shown on the surficial geology sheet of the Rockland folio.

Rockport.—The western part of this town is occupied mainly by schists injected by granitic rocks, and the eastern part largely by slates and argillaceous schists; both these rocks are poor road materials.

Quartzite and quartzite conglomerate occupy small areas in the vicinity of Rockport and on Pine Hill north of Clam Cove. The character and road-building quality of this rock have been discussed under the town of Camden (pp. 31–32).

Crystalline limestone has been quarried for many years for the manufacture of lime in the northern part of the town of Rockport,

near Lilly Pond. This rock is similar in most respects to that quarried at Rockland, the quality of which is shown by test of specimen No. 26 of Table 1, and the reader is referred to the descriptions for the town of Rockland (p. 34) for a discussion of its road-making qualities. Its use alone is not to be recommended, but it may be advantageously used as a top dressing for more resistant material, such as quartzite or granite.

Gravel is very abundant in this town, its distribution and the location of gravel pits being shown on the surficial geology sheet of the Rockland folio. One of the best deposits occurs in the vicinity of West Rockport, and has been utilized to a considerable extent in road construction. Marine clays are not abundant.

South Thomaston.—South Thomaston shows an unusual variety in its hard rocks, the eastern portion, from South Thomaston village to Owls Head, consisting largely of schists injected by granitic and by basic igneous material. These hard rocks are not well adapted to road construction. The portion of the town extending southwestward from Rockland Harbor to Weskeag River is underlain by argillaceous schist and slate, also of poor road-making value. Small areas of limestone occur in the western part of the town, and might furnish material for a top dressing on roads.

A large hill north of the northern end of the Weskeag River estuary is composed principally of quartzite known as the Weskeag quartzite. This rock is compact, fine-grained, and buff to gray in color.

Under the microscope it is found to consist of quartz (40 per cent) in interlocking grains, and orthoclase feldspar and white mica (muscovite) constitute 50 per cent. Accessory minerals present in small amounts are magnetite, plagioclase feldspar, zircon, tourmaline, biotite, and leucoxene.

The test on this rock—No. 24 of Table 1—shows it to be hard and fairly tough, with rather high resistance to wear and a fair cementing value. It constitutes the best hard-rock material available in this town, and its use may be recommended on the streets of Rockland, particularly if a top dressing of trap rock or of limestone be added.

Gravels are abundant and widely distributed in the town, and are at present the principal material used in road construction. Clays underlie large areas, and the roads in these districts might be notably improved by the admixture of fine gravels or sand.

St. George.—The town of St. George is largely occupied by schists injected by granite and by considerable masses of basic rocks, diabase and diorite. The schists and granites are for the most part of poor road-making value, but most of the basic rocks would be excellent. The latter are confined mainly to the region extending from Long Cove northeastward slightly beyond the northern border of the town, and they have been quarried in a small way at a number of points in

the vicinity of St. George and northeastward. The specimen collected from a small "black granite" quarry, one-half mile northeast of Long Cove post-office, may be regarded as typical of much of this material. This quarry is operated largely for monumental stone. The rock is a medium-grained, dark greenish-gray gabbro.

Under the microscope it is seen to be granular in texture and to consist largely of nearly fresh plagioclase feldspar (50 per cent), augite (17 per cent), hypersthene (12 per cent), and hornblende (13 per cent), with small amounts of magnetite, biotite, and pyrite.

The test—No. 10 of Table 1—shows that it is hard but not very tough and has fairly high resistance to wear and good cementing value. It should make a thoroughly satisfactory road material.

The 80-foot hill southeast of the quarry just referred to is also formed largely of rock which is similar, though somewhat finer in grain. This should, if anything, be somewhat superior to the rock from the quarry for road construction.

The 40-foot hill one-half mile north from the center of Tennants Harbor village is also composed of medium-grained diorite, and numerous masses of diorite of considerable size occur in the vicinity of St. George village. Some of these have been quarried for building stone. The location of the quarries is shown in the Rockland [a] folio.

Trap rock could be cheaply quarried in most of these localities, and, with a short haul to the St. George River or to the outer coast, could be transported by water to Thomaston, Rockland, or even to greater distances.

Gravels are abundant and widely distributed over the town.

Thomaston.—The western part of the town of Thomaston is occupied by slate and argillaceous schist. A broad band of crystalline limestone extends across the central portion, while in the eastern portion occur alternate bands of limestone, quartzite, and schist. The quartzite with perhaps a top dressing of limestone would be the most desirable hard-rock road material available within the town, though trap rock from the town of St. George could be cheaply obtained.

Gravels are present only in moderate amount, though probably sufficient for local needs.

Union.—The hard rocks of the town of Union are largely schist injected by granitic material, though there are small areas entirely of granite and a few narrow bands of limestone. The rocks in general are of poor quality for road construction, and the abundant local supplies of gravel will have to be largely depended upon.

Vinal Haven.—The island of Vinal Haven is composed largely of granite of medium grain, though in the northern portion there is a considerable area occupied by rhyolite, some of which is massive and would make excellent material for road construction. A small area

[a] Loc. cit. (see page 8).

of andesite similar to that occurring near North Haven village occupies the point west of Carvers Cove. The road-making properties of this andesite have already been described (p. 33). A considerable portion of Calderwood Neck is occupied by slate and schist of the Calderwood formation. The latter, though more quartzose than many of the slates and schists of Maine, is nevertheless of poor quality for road construction.

The best road materials on this island are the traps (diorites and diabases) which occur south and southwest of the village of Vinal Haven, on the extreme northern shore of the island from Youngs Point to Hopkins Point, and in the extreme eastern part of the island near Coombs Hill and Barley Hill. Their distribution is shown in detail in the Penobscot Bay folio. The most abundant rock types in the Barley Hill region vary from diorites to diabases and are mostly rather fine-grained. The principal mineral constituents of the more basic varieties are plagioclase feldspar, hornblende, and augite, the last two minerals occurring in complex intergrowth with each other. Small amounts of magnetite also occur. Other rocks of this area are more feldspathic, lighter in color, more granular in texture, and contain biotite in addition to the above-mentioned minerals. They thus are intermediate between diorites and true granites.

In the vicinity of Vinal Haven diabase has been quarried for monumental purposes, the quarry being located west of Sand Cove. The rock is almost black in color and is fine-grained.

Under the microscope it is seen to be an olivine-bearing diabase, consisting in descending order of an abundant network of slender crystals of unaltered plagioclase feldspar (61 per cent), between which occur augite (18 per cent), greenish olivine (11 per cent), magnetite (4 per cent), hypersthene, hornblende, and black mica (biotite). A small amount of secondary serpentine has resulted from the decomposition of the olivine.

The tests on this rock—No. 3 of Table 1—show that it is hard but not very tough; it possesses high resistance to wear and good cementing value.

Brimstone Island, 1½ miles southeast of Vinal Haven, is made up of trap of excellent quality, but the island is so exposed to the ocean that shipment would be impossible.

The trappean rocks of Vinal Haven, while in general not so fine-grained as some occurring elsewhere in the State, notably in Washington County, are still many of them of excellent quality for road construction. In locating a quarry the finer-grained varieties should be sought for. They are present in large quantity and are situated near deep water, so that they could be cheaply shipped by water. They have the advantage over deposits located farther east in the State in being nearer to the larger cities of Maine where the demand for them would probably be greatest.

WARREN.—The town of Warren consists largely of schist injected by granitic material, though areas composed entirely of granite occur near the Waldoboro line and west of South Pond. Limestone also occurs near North Warren, and is quarried for the manufacture of lime. The best results from the use of local hard-rock material may be obtained from roads constructed of crushed granite with a top dressing of limestone. Gravels are also abundant and widely distributed.

WASHINGTON.—The hard rocks of the town of Washington are largely schists injected by granitic material. These are of poor road-making quality, and the gravels furnish the best local supply.

PENOBSCOT COUNTY.

The portion of Penobscot County falling within the area covered by this report is occupied almost exclusively by slate and argillaceous schist, though a small area of medium-grained granite embraces the villages of Enfield and Lincoln, and several smaller granite areas enter the southeastern and little-settled portions of the county. The slates in the vicinity of Bangor may be taken as typical of those in most parts of the county so far as their road-making qualities are concerned. The rock in this locality is fine-grained, fissile, gray slate cut by numerous irregular stringers of white quartz. It is quite soft and crumbles very easily. It is quarried and crushed in the northern part of the city along the Kenduskeag River, and also about 1 mile below Bangor on the west bank of the Penobscot River at High Head. The results obtained from the use of this rock on the roads have been in every case highly unsatisfactory, the material soon grinding up so as to become muddy in wet weather and dusty in dry weather.

Microscopic examination of the slate from High Head shows that it consists essentially of quartz and of sericite, with small amounts of magnetite and limonite.

The tests of specimen No. 23, Table 1, show that it has a fair cementing value. The wearing qualities were not tested in the laboratory, but actual experience in the use of the material has plainly demonstrated that they are very poor. The use of this rock should be avoided and recourse had to the gravels which are very abundant along the Penobscot River and are for the most part of excellent quality.

At High Head there are large deposits of sand and gravel which are clean, of medium coarseness, and contain only a small proportion of slate pebbles, most of them being granite or quartzite. This gravel has been used extensively on the roads with excellent results. Gravel pits are located at Brewer, across the river from Bangor, at Veazie, and along Valley avenue north of Bangor. These gravels are undoubtedly the best local material, and far superior to the slates.

SAGADAHOC COUNTY.

The rocks of this county are almost entirely schists injected by granitic material, both being intruded by numerous small trap dikes. The quality of the schists and associated granite and granite-gneiss is well exemplified by the tests made upon a sample of this material collected at Woolwich, opposite Bath. This rock is composed of alternate bands of gneiss and mica-schist, and for the most part is coarse-grained and light gray in color.

Under the microscope it is seen to be composed essentially of quartz (46 per cent), orthoclase feldspar (35 per cent) somewhat altered with the development of kaolin, and 9 per cent of black mica (biotite). Accessory minerals present in small amounts are microcline and plagioclase feldspar, muscovite, magnetite, hematite, and apatite.

The test of this material—No. 16 of Table 1—shows the rock to be of low toughness, medium resistance to wear, and good cementing value. This particular sample probably yields better results than most rocks of this type, which do not as a rule make satisfactory road materials because of their schistose structure, coarse grain, and large amount of mica.

In the township of Topsham pegmatite of granitic composition—essentially an exceedingly coarse granite—is quarried for its feldspar constituent, and the refuse from the quarries is used to some extent upon the roads in this township and in the township of Brunswick, Cumberland County. Most of the roads thus constructed are private roads leading to the quarries, and very little has been used upon the public highways.

The tests on this material (No. 17 of Table 1) show it to have exceedingly poor wearing qualities. Its hardness and toughness were not tested, but would unquestionably be very low. While this material, because of its cheapness and accessibility, may be used to advantage on quarry roads, its use on the public highways should be avoided.

Gravels of good quality for road making are abundant in most parts of the county, particularly near the Kennebec River. Along this river also there are considerable areas of sand flats, where the roads may be improved by mixing with the sand the marine clay so abundant along the larger estuaries.

SOMERSET COUNTY.

The rocks of Somerset County, so far as known, are largely argillaceous schists and slates, with considerable areas of intrusive granite. The road-making qualities of these types of rock have already been fully described. Small amounts of limestone are present in a few localities, one of them occurring at the falls near North Anson.

Such supplies might be utilized in road construction as a top dressing upon a granite foundation. The gravels which are abundant and of good quality must form the principal local supply.

WALDO COUNTY.

The northwestern half of Waldo County is composed largely of slate and argillaceous schist. An area of similar schist extends southwestward from Bucksport to Stockton Springs, Belfast, and to the county line. In these areas the gravels will have to be relied upon as the local source of road material. Considerable areas in the towns of Palermo, Liberty, Montville, Knox, Brooks, Swanville, Searsmont, Lincolnville, Northport, and Belmont are occupied by similar slate and schist more or less injected by granitic rocks. These injected schists are but little superior to the normal slate and schist for road building. A large area of granite occurs in the northeastern part of the county, its general outline being shown on the map (Pl. I). This granite is for the most part of medium grain and is quarried for building purposes at a number of points. In common with most granites it is low in toughness and cementing value, but if used with a top dressing of trap rock would probably be the best local hard-rock material afforded by the county. Black granite (olivine diabase) is quarried in but one place, in the town of Lincoln, about 3 miles west from the coast, but the rock is too coarse-grained to be of first quality for roads.

Gravel is abundant and widely distributed throughout the county, particularly along the Penobscot River, and forms the principal source of road material.

Islesboro.—The rocks of Islesboro are largely slate and schist, but there are also small associated areas of quartzite and of limestone, the latter mostly impure. The slate and schist are wholly unsuitable for use on the roads, but the quartzite could be used as a foundation, with a top dressing of limestone to give a good cementing value. In the extreme southern part of South Islesboro there are also small areas of North Haven greenstone which could be used to advantage.

WASHINGTON COUNTY.

The rocks of Washington County are largely shale and argillaceous schist, quartzose schist, and granite, basic intrusive rocks and minor amounts of surface volcanic rocks of both acid and basic varieties. In the eastern part of the county there are several small areas of sandstone and conglomerate. The distribution of the rocks is rather imperfectly known, but is indicated in a general way upon the map (Pl. I). Much of the county is thinly settled and detailed studies were made only in a few townships, as described below. The northwestern half of the county consists largely of shale and schist and the gravels here must be the principal source of road material. Granite

extends as a single broad belt from Millbridge through Jonesboro and thence northeastward to the vicinity of Calais. The volcanic rocks so far as known are confined to the southeastern part of the county.

Calais.—The commonest type of hard rock in the vicinity of Calais is a schist injected by granite. This rock is crushed for road use near the Calais-Milltown road, about 1 mile west of the city of Calais. The rock is satisfactory for road use only when a top dressing of gravel is applied, and its continued use can not be recommended in view of the occurrence within the city itself of considerable masses of a coarse gabbro which when crushed would probably make a much firmer and better cemented roadbed. Small amounts of a trap, shown under the microscope to be an altered basic andesite, occur along the American bank of the St. Croix River about 1 mile southeast of Calais, but the quantity of this material is too small to render it of value as road material. The best materials available for road construction in this region appear to be the diorite and diabase which is associated with the granite 2 or 3 miles southeast of the city. These rocks are fine-grained, light to dark gray in color, and could easily be quarried and transported over a good road to Calais. Such material has been used to some extent on the Calais-Red Beach road and has given excellent satisfaction.

East Machias.—The rocks of this town are largely quartz-schist, with minor areas of both acid and basic volcanic rocks and small amounts of intrusive trap. One and one-half miles southwest of East Machias occurs an exposure of an altered andesite showing phenocrysts of feldspar one-eighth to one-fourth of an inch long in a blue-gray fine-grained matrix.

Under the microscope this rock is seen to consist of plagioclase feldspar in a fine-grained groundmass of alteration products, mainly epidote and chlorite.

A short distance west of East Machias are numerous exposures of a grayish-green rock, which is an altered rhyolite and shows large phenocrysts of orthoclase feldspar in a fine-grained bluish to purplish-gray groundmass consisting of quartz, orthoclase, plagioclase, and epidote. This rock should be of moderately good road-making quality.

South of East Machias and about one-half mile north of Randalls Point is a large hill of dark greenish-gray diabase forming an immense supply of excellent road material.

On microscopic examination this rock is seen to be an altered diabase consisting of much-altered plagioclase feldspar and some partly chloritized augites.

Gravels are abundant in most parts of the town.

Eastport.—The town of Eastport includes Moose Island, in the extreme eastern part of Washington County. The rocks of this town are largely rhyolites and diabase with small amounts of associated

shale—the latter wholly unsuitable for road building. The more massive phases of the rhyolite, such as occur just northeast of the railroad station at Eastport, along the shore opposite Clark Ledge in the northern part of the village of Eastport, and on the large hill east of Carrying Place Cove, would make excellent material for light-traffic roads.

The use of rhyolite, however, can hardly be recommended in view of the presence in such abundance of trap rock, which is even better for road-building. This rock underlies most of the city of Eastport and occupies nearly all of Shackford Head and Estes Head. Certain portions are more massive than others, but almost all of this material would give excellent results on roads. Some of the more massive phases occur on the hill a short distance northwest of the railroad station at Eastport, where it has been quarried at a number of places and used on the roads in the city. Massive phases also occupy Shackford and Estes Heads. At both of these points the quantity available is practically limitless, and the material if quarried at the waterside could be loaded directly into vessels for shipment. The harbor protection at these points is excellent and the shore falls off abruptly so that vessels can approach close to the beach even at low tide. These two localities are perhaps the most promising in the whole State for the cheap quarrying and loading upon vessels of the best quality of rock for road construction. From the hill northwest of the station at Eastport the trap rock could also be readily shipped by rail.

The rock from Estes Head is a highly altered diabase, greenish-gray in color and of moderately fine grain.

Under the microscope it is seen to consist essentially of altered plagioclase feldspar (58 per cent), augite (13 per cent), much altered to chlorite (18 per cent), with accessory amounts of apatite and epidote.

The physical tests of specimen No. 6 of Table 1 show that the rock is hard and tough, with high resistance to wear and good cementing value. It should make an excellent road material even for heavy traffic.

Gravels of good quality for road making are abundant on the island and have been utilized at many points. One of the best exposures occurs just south of Johnson Cove along the railroad.

Jonesboro.—Much of this town is underlain by granite of medium grain, but the eastern portion is occupied largely by quartzitic schists with associated acid and basic volcanic rocks and masses of intrusive trap.

One of the largest trap masses occurs at Black Head on the northeast shore of Englishman Bay, where it intrudes quartzose schist as a sill-like mass of greenish-gray color, 20 to 30 feet thick, extending back from the shore at least 1,000 feet.

Under the microscope this rock is seen to be a highly altered diabase, composed essentially of altered plagioclase feldspar (56 per cent) and augite (14 per cent), much altered to chlorite (27 per cent). Magnetite is present in small amounts, as also is the secondary mineral leucoxene.

The tests on this rock (No. 5 of Table 1) show it to be a hard and tough rock with very high resistance to wear and very good cementing value. It should give excellent results even under heavy traffic. By the construction of a wharf the material could be shipped at a comparatively low cost to various points on the New England coast.

One and one-half miles northwest of Black Head, near Shoppees Point, is an exposure of a flow, a fine-grained rhyolite porphyry, consisting essentially of small orthoclase and quartz phenocrysts embedded in a fine-grained groundmass of quartz, orthoclase, and some hornblende. This would make good material for light-traffic roads in this vicinity, though its shipment to a distance would be difficult because of the shallowness of the bay opposite this point.

Lubec.—Fine-grained trap is not very abundant so far as known in this township, though it constitutes most of the Rogers Islands and Dudley Island. The greater portion of the peninsula north of Lubec (Seward Neck) is made up of rhyolites which are in part massive flows and in part tuffs, etc. The more massive varieties of these rocks would furnish excellent road material for light-traffic. The most abundant basic rock of this township is a coarse diabase, which is exposed abundantly in the village of Lubec and along the west shore of Johnson Bay, and forms most of the hills in the region between Lubec village and West Quoddy Head, and also in the region southeast of West Lubec. While this rock does not possess the toughness of most of the finer-grained traps it would nevertheless be excellent material for road use. At West Quoddy Head the coarse diabase intrudes highly quartzitic slates which would themselves furnish excellent road material. If the two rocks were quarried together, as could readily be done at a large number of places, the resulting material should be of high road-making quality.

Trap rock occurs abundantly on Long Island in South Bay and in the vicinity of Basset Cove, while coarse diabase constitutes the bulk of Black Head at the mouth of Federal Harbor. Small areas of these basic rocks are abundant throughout this part of the town and would furnish an abundance of material for local use.

Gravels of good quality are very abundant on Lubec Neck and in most other parts of the township.

Machias and Machiasport.—The rocks of the town of Machias are largely schists with varying amounts of acid and basic volcanics and of basic intrusive rocks. The schists of this region are quartzitic, fine-grained and highly jointed, and could probably be used to good

advantage on the roads. Outcrops of favorable shape and position for quarrying occur at numerous points within a distance of 2 miles from Machias, along the road to Machiasport.

Two and a quarter miles southeast of Machias along the south side of the Machiasport road is a large hill of grayish-green fine-grained altered diabase.

Under the microscope this rock is found to consist largely of plagioclase feldspar, augite (6 per cent), largely replaced by chlorite (44 per cent). There are minor amounts of magnetite and leucoxene.

The physical tests on this rock (No. 4 of Table 1) show it to possess medium hardness, rather low toughness, with fairly high resistance to wear and good cementing value. It should make a satisfactory road material, and a quarry could easily be operated on the hillside and the material hauled to Machias. Similar outcrops occur all along the road between this hill and Bucks Harbor in Machiasport.

Just north of the village of Machiasport is a high cliff of greenish-gray diabase not so highly altered as that just described, and consisting essentially of plagioclase and augite. The rock should make an excellent road material and the cliff is ideally located for quarrying. The material could be shipped by water from Machiasport or hauled to Machias.

Pembroke.—The rocks of the northern part of the town of Pembroke are little known, but a large hill of a rock, which is probably a diabase porphyry (porphyritic trap), occurs just north of Ayers Junction and would probably form excellent material for road use. Similar rock outcrops along the railroad track 2 miles or so west of the Junction, and trappean rocks occur at a number of points along the road from the Junction toward Pembroke. In the southern part of the township a mass of trap rock forms a chain of hills from one-half to three-fourths of a mile broad, extending in a northwesterly direction from East Bay. Trap also occurs along the southwest shore of Pennamaquan River about opposite the mouth of Herseys Cove.

Masses of coarse diorite similar to that found so abundantly in the town of Lubec form the hill just west of Garnet Point and the hill east of the mouth of Herseys Cove, and also form the ridge just east of Pembroke village. This last occurrence forms the best and most available hard-rock road material for the village of Pembroke. Coarse diabase also occupies large areas on the peninsula between Youngs Cove and Falls Island.

Gravels are particularly abundant near the village of Pembroke and from there southeastwardly to Herseys Cove, and they have been used to a large extent on the roads. On certain parts of the road from Pembroke to Leightons Point beach gravel composed entirely of shale pebbles has been used. These split and grind up

quickly under traffic, and a poorer road material could hardly have been selected. Along the shores near by are numerous occurrences of the best quality of trap.

PERRY.—The rocks of the northeastern part of the town of Perry, from the vicinity of Perry village northward, are principally conglomerates and sandstones of the Perry formation with interbedded basic lava flows. The latter are exposed on the hills just north of Perry village and would furnish excellent material for the roads. The southern part of the township is occupied mainly by trap (diabasic lava flows) and by rhyolite and small associated amounts of shale. Phases of the rhyolite which are usually reddish or pinkish in color are massive and would be excellent material for use on the roads, but a better material is available in the traps which form the hill just southwest of the reservoir dam near Perry village and which occupy most of the east shore of East Bay from its head nearly to Birch Point. Exposures of this rock also occur along the Perry and Pembroke roads about one-half mile northwest of the toll bridge to Moose Island. This trap rock has been used to good advantage on the Perry roads in the vicinity of Pigeon Hill.

As an example of a very poor material used on the roads may be cited the red shale dug at the upper reservoir dam near Perry. This rock because of its crumbly character requires no crushing and can be cheaply and easily dug, but upon the roads it soon wears down into a sticky red mud or dust, and is one of the poorest materials which could possibly be obtained for road use. A quarter of a mile southwest of this reservoir dam occurs a large hill of trap rock which would furnish the best of road material.

The gravels are not particularly abundant in this town, most of the area being bare rock or occupied by a light covering of glacial drift or by marine clays.

YORK COUNTY.

The rocks of York County are principally impure quartzites or quartzose schists, granites of various types, and schists which have been injected by granitic rocks. These rocks have been intruded by numerous dikes of dark-colored trap rocks. Gravels are abundant in all parts of the county, and along the coast and the larger rivers and estuaries marine clays also occupy considerable areas.

The distribution of the quartz-schists is indicated on the map (Pl. I). They are well exposed near Kittery and South Berwick and along most of the coast from York to Kennebunkport. They are prevailingly grayish to greenish, fine-grained rocks, usually showing distinct bedding planes and often a faint schistosity. They are composed essentially of irregular quartz grains with varying amounts

of dark-colored mica (biotite), feldspar (orthoclase), and some decomposition products derived from the latter. They are usually steeply inclined, and show considerable variations in strike, though most commonly trending northeast-southwest.

The granites vary considerably in texture and composition. Their characters where they have been quarried have been fully described by Professor Dale.[a] So far as known they have been little used in improving the roads, and their value for this purpose is not so high as that of the quartz-schists and the trappean rocks.

Dark-colored igneous rocks occur as parallel-walled dikes and occasionally as irregular stocks cutting the schists and granitic rocks in nearly every part of the county. The dikes vary in width from a few inches to 30 feet or more, though the great majority are less than 5 feet. No traveler along the coast can fail to notice these dikes, at times projecting into the sea as wall-like masses, and again weathered back so as to form peculiar chasms and gaps in the schist. Frequently they show a columnar structure developed at right angles to their walls.

The areas occupied by schists intimately injected by granitic rocks lie principally in the northwestern part of the county, as is shown upon the map. These areas were not studied in detail since their rocks, as has already been stated, are of poor quality for road construction.

The gravels are widely and irregularly distributed, and, as in all other parts of the State, they are the principal materials used on the roads. Their variety and abundance, however, are so great that few detailed studies upon them could be attempted in the small time available for this work. Only a few important deposits were examined.

Glacial bowlders lying free upon the surface or only partially embedded and commonly known as field stones are abundant in many parts of the county, especially in the higher portions lying a little distance back from the coast. These materials have been crushed and utilized to some extent, notably on the State road from Springvale to Emery Mills, in the towns of Sanford and Shapleigh. The results here have been excellent and should encourage the use of similar material elsewhere. Detailed observations upon them are given below.

The towns not included in the following list were not studied in detail.

Alfred.—The most available material in this town is a fine sandy gravel usually obtained from the roadsides. It compacts into a firm roadbed and seems to be giving satisfaction. In the country east and northeast of Alfred the rock is a medium-grained granite

[a] U. S. Geol. Survey Bul. 313, pp. 175–183.

which would probably not be as satisfactory for road use as the gravel and would be much more expensive.

Biddeford.—The rocks of this town are largely granitic, but so far as known crushed granite has not been used to any important extent upon the roads, though granite paving blocks quarried in Biddeford have been used in Saco.

The northern part of the town of Biddeford, though largely granite, contains some sedimentary rock and some masses of intrusive trap. One of the largest trap masses occurs at Hills Beach, situated on the south bank of the Saco River, 5 miles southeast of the city of Biddeford. A number of greenish-gray trap dikes were noted here, the largest being 11 feet wide and traceable for 500 feet southeast from the river.

Under the microscope the rock is seen to be an altered diabase porphyry consisting largely of altered plagioclase feldspar (58 per cent), augite (15 per cent), much altered to chlorite (15 per cent), with minor amounts of magnetite, biotite, and secondary pyrite and calcite.

The physical tests of this material (No. 2 of Table 1) show the rock to be of medium hardness, rather low toughness, high resistance to wear, and excellent cementing value. It should make a satisfactory road material when used alone, and because of its high cementing value should make a valuable top dressing for granite roads. The rock is intrusive into quartz-schists, which are also of good road-making value. The two could be quarried together with excellent results. The rock could be shipped by the Saco River or hauled to Biddeford.

Eliot.—Granite from numerous hills around Eliot has been used with moderately good results on the near-by roads. In the gravel around Frost Hill about two-thirds of the pebbles are granitic in composition, while the other third is made up of quartz-schist and more fissile rock. It contains a considerable percentage of clay matrix, probably more than is desirable in a gravel to give the best results as a road material.

Kennebunkport.—The prevailing rocks of this town are granites, though there are small areas of schist. Around Cape Porpoise and on Redin Island there are numerous basic dikes, mostly only a few feet in width, cutting granitic rocks and quartzitic schists. Similar dikes occur on the coast east of Kennebunkport, the largest one observed, opposite Pumpkin Island, being 20 to 30 feet in width.

Kittery.—The rocks of this town are largely quartzitic schists intruded by dikes and stocks of dark-colored basic rocks. A number of these dikes trending northeast and southwest are exposed near the Piscataqua River about one-half of a mile north of Kittery depot. The widest of these is 25 feet, while a number of others are

10 feet in width. If the quartzitic schists were quarried with the latter an excellent road material would be produced. A second exposure of basic rock occurs a quarter of a mile northeast of the Kittery-Portsmouth bridge, near the junction of the Portsmouth and the navy-yard roads. The rock exposed here is a gabbro of dark gray color and coarse grain, and is well exposed in a number of small pits from which material has been quarried for use in foundations, etc. The rock covers an area of at least one-eighth of a square mile and forms a small knoll. It could be readily quarried and transported to Kittery village or to Portsmouth.

Microscopic study of this rock shows it to be an altered gabbro composed essentially of plagioclase feldspar (52.5 per cent), considerably altered with the development of kaolin (16.7 per cent), augite (14.3 per cent), also considerably altered to chlorite (9.4 per cent). Magnetite is present in small amounts as an accessory mineral, and small amounts of secondary biotite, quartz, and calcite are also present.

The results of the physical tests upon this rock are given under No. 11 in Table 1. These show the rock to be fairly hard, but not very tough. It has rather high resistance to wear and excellent cementing value, and should give good results under ordinary conditions of traffic.

Quartz-schists are exposed at numerous places along the road between Kittery and South Berwick, and along the York road between Kittery and the southern portion of the town of York. A specimen which may be regarded as typical of these schists was collected on Kittery Point, at the side of the trolley road, 2 miles east of Kittery village. This rock is a gray to purplish schist, so massive that it splits almost as readily across the bedding planes as parallel with them.

Under the microscope its principal minerals are seen to be quartz (66 per cent) and about 24 per cent dark-colored mica (biotite). Accessory minerals present in small amounts are magnetite and titanite, and small amounts of secondary calcite and chlorite are also present.

Results of the physical tests on this rock are given under No. 20 of Table 1. They show the rock to be of medium hardness and toughness with high resistance to wear and good cementing value. It is slightly inferior in hardness and toughness to the quartz-schist quarried at Saco. Although it would make a good road material if used alone, its value would be enhanced if the quarry site could be so chosen as to include in the quarrying operations one or more of the trap dikes which intersect this material in many places. Such a mixture would possess greater cementing power than the schist alone. Trap might also be used to advantage as a top dressing.

Saco.—The rocks of the town of Saco are largely quartz-schists with intrusive trap dikes and small amounts of intrusive granitic rock. The quartz-schists are quarried by the city of Saco for use upon its roads from a quarry located near the Boston and Maine depot. The rock here is compact, fine-grained, and banded in greenish to purplish gray.

Microscopic examination shows that it is a fine-grained rock, consisting essentially of a finely felted mass of quartz, calcite, and sericite, with very little tendency toward a parallel arrangement of any of the grains. Accessory minerals present in small amounts are magnetite, actinolite, biotite, and a small amount of titanite. The carbonate of lime (calcite) constitutes 17 per cent by weight of the rock in the specimen submitted to examination.

The results of the tests upon this material (No. 21 of Table 1), show the rock to be hard and exceedingly tough, with high resistance to wear and good cementing value. The cementing value is doubtless enhanced by the presence of a considerable quantity of carbonate of lime. The rock is well adapted for use on the roads of Saco and Biddeford, with their heavy traffic to and from mills. In the quarry at Saco a diabase dike cutting the schists is quarried with them, and probably adds to the value of the material.

Sanford.—East and northeast of Springvale and Sanford gravel of a sandy character is very abundant and has been used in road construction. To the west the gravels are less abundant and the prevailing rock is granitic gneiss associated with mica-schist and with some granite and pegmatite. These rocks make very poor road materials and their use should be avoided. The best and most available material for the parts of the town where gravels are scarce is field stone or loose bowlders. About two-thirds of these are diabase and related rocks (traps). This material has been crushed and used with excellent results on the State road from Springvale to Emery Mills, in the town of Shapleigh. It is crushed with a portable crusher, and the trappean constituents give the material a cementing value sufficient to form a firm, hard road.

Wells.—The rocks of this town are largely granitic in character, though quartz-schist is predominant along the coast. As in other parts of the county, numerous dark-colored dikes of trap intrude both of these types of rock. A number of these dikes are exposed from Ogunquit to Bald Head along the coast. Several dikes near Ogunquit, south of Perkins Cove and south of Bald Head, have a width of 20 to 30 feet.

One of the largest trap masses observed in this town occurs 1 mile north of Ogunquit, opposite Eldredge's hotel, along the trolley line. It has an exposed width of 30 to 40 feet, and can be traced across

country for 1,000 feet, forming a pronounced ridge. It is a gabbro-diabase of dark-gray color and medium coarseness.

Microscopic examination of this material shows it to be composed essentially of plagioclase feldspar (46 per cent), somewhat altered to kaolin (8 per cent), and augite (23 per cent), and extensively altered to chlorite (15 per cent). Accessory minerals present in small amounts are magnetite and biotite. A small amount of secondary pyrite is present.

The results of the physical tests—No. 9 of Table 1—show that the rock is of medium toughness, high resistance to wear, and excellent cementing value. It should make a satisfactory road material, especially under heavy traffic. It could be easily quarried and transported over the trolley road to Saco, Biddeford, or Portland.

SUMMARY AND CONCLUSIONS.

The observations detailed in the preceding pages show that the coastal region of Maine is in general well supplied with hard-rock road materials of good quality. The presence in the extreme southern part of the State of extensive deposits of quartzitic schist of excellent road-making value compensates in a large degree for the scarcity there of the deposits of trap, so abundant farther east. The latter, though at present almost entirely undeveloped, are in general fully equal to those found in other New England States. They are present in large amounts, and are frequently so situated that they can be cheaply quarried and shipped by water.

In most parts of the State where road materials of first quality are absent these may be shipped in by rail or by water from other points in the State, usually not far distant, and utilized either alone or as a top dressing for foundations built of the poorer local materials. The waste from most of the "black-granite" quarries of Maine could be crushed to furnish excellent road material.

Of the principal cities of Maine, Portland has a good local supply in its quartzitic schist, but could also import trap for a top dressing from Washington County or from the Wells Beach dike. Biddeford and Saco are well supplied with quartzitic schist with which trap from Hills or Wells beaches could be utilized. The Biddeford granite could also be used mixed with trap or used with a top dressing of the latter. Lewiston and Auburn have no good local hard-rock supply, but the North Jay granite is near by, and with a top dressing of trap imported from some other part of the State this would make excellent roads. Brunswick has the Harpswell trap as an excellent near-by material, which could be used alone or with granite. Augusta has the Hallowell granite, which needs only a top dressing of trap or limestone as a binder. Bangor has no good local supply of hard rock, but excellent trap could be cheaply brought in by water from North Haven and adjacent islands in Penobscot Bay.

GLOSSARY OF SCIENTIFIC TERMS USED IN THIS REPORT.

Acid.—Containing a high percentage of silica-bearing minerals. Opposed to basic.

Andesite.—A very fine-grained volcanic rock (lava) consisting when fresh essentially of plagioclase feldspar and pyroxene, hornblende or related dark-colored minerals.

Argillaceous.—Originally clayey in composition.

Basic.—Containing a low percentage of silica and a relatively high percentage of dark-colored, iron-bearing minerals (hornblende, pyroxene, etc.).

Biotite.—Black or brown mica. A potash-aluminum-magnesium-iron silicate.

Calcareous.—Containing calcite.

Calcite.—Carbonate of lime ($CaCO_3$).

Chlorite.—A greenish, soft, platy mineral. Chemically a silicate of aluminum and magnesium (or iron). Often a decomposition product from pyroxene or hornblende.

Chloritized.—Altered to chlorite.

Crystalline.—Made up of crystal grains.

Diabase.—A dark-colored igneous rock consisting, when fresh, mainly of grains of plagioclase feldspar and pyroxene, usually with some magnetite. Normally shows a characteristic interlocking of the mineral grains. (See Pl. II.)

Diorite.—A dark-colored igneous rock consisting, when fresh, mainly of grains of plagioclase feldspar and hornblende. Texture usually granitic.

Dike.—A mass of rock which has been erupted through a narrow fissure and is therefore more or less parallel-walled.

Dip.—The inclination from the horizon (usually given in degrees) of a bedding plane, joint plane, dike, or other structural plane, in a rock.

Drift.—Materials deposited by a continental glacier or by waters flowing therefrom.

Erosion.—The wearing away of portions of a rock mass by such natural agencies as stream, ice, or wave action.

Feldspar.—The feldspars are silicates of aluminum with various amounts of potash, soda, and lime. Hard minerals, with good cleavage in two directions. Usually white to pink or gray in color.

Gabbro.—A coarse-grained crystalline rock composed, when fresh, mainly of plagioclase feldspar and pyroxene usually with some magnetite. Differs from diabase mainly in possessing a granitic rather than an interlocking or diabasic texture.

Gneiss.—A coarsely foliated or laminated rock.

Granite.—An igneous rock usually consisting, when fresh, of a crystalline aggregate of quartz, feldspar, and mica, or hornblende. Usually gray to pinkish in color.

Granitic.—Granite-like in composition or texture.

Greenstone.—A comprehensive name applied to any dark-greenish igneous or metamorphic rock.

Hornblende.—A group of moderately hard minerals, usually dark green to black in color. Silicates of lime, magnesium, iron, and aluminum. A common constituent of diorites and many granites.

Igneous.—A term applied to rocks that have solidified from a molten condition.

Joints.—Rather large and continuous fracture planes in rocks, usually steeply inclined.

Magnetite.—Magnetic iron ore—iron oxide (Fe_3O_4); hard, metallic, black, and opaque.

Metamorphic.—A term applied to rocks whose constituents have been recrystallized either with or without chemical change and which have been subjected at some time to heat and pressure.

Mica.—Minerals distinguished by a very easy cleavage whereby they can be split into very brilliant elastic leaves. All micas are silicates of alumina, containing alkalies with oxides of iron and magnesium. Common isinglass is a form of mica. Muscovite and biotite are the commonest varieties.

Muscovite.—Common or potash mica. Essentially an aluminum-potassium silicate. Usually colorless or light brown.

Orthoclase.—Potash feldspar. Usually white to flesh-pink. The common feldspar of granite.

Pegmatite.—Essentially a very coarse granite occurring in irregular dikes or lenses in granite and some other rocks.

Plagioclase.—A name applied to a group of feldspars which are silicates of aluminum and soda or of aluminum with both soda and lime. Usually white to gray in color. Often distinguishable in bright light from the potash feldspars by the presence of delicate striations on the principal cleavage face.

Polarized light.—Light vibrating in one plane only. Used in study of thin sections of rocks under the microscope to better determine the optical characters of certain minerals.

Porphyritic.—Possessing the texture of a porphyry.

Porphyry.—Any rock showing distinct crystals embedded in a groundmass of relatively much finer grain.

Pyroxene.—Hard minerals usually dark green or brown to black in color. Silicates of magnesia with variable proportions of iron, lime, and alumina. Distinguished from hornblende by cleavages intersecting approximately at right angles rather than at an acute angle.

Quartz.—Oxide of silicon (SiO_2). Hard. Usually white to gray; fractures irregularly; a common constituent of granites.

Quartzite.—A rock originally a sandstone, the pores having subsequently been partly or completely filled by quartz through deposition from percolating waters.

Sandstone.—A rock originally a sand, but subsequently compacted and the grains partially cemented together so as to form a coherent rock.

Schist.—A crystalline rock having a foliated or parallel structure and splitting easily into slabs or flakes, less uniform than in slate.

Schistose.—Showing the foliated structure characteristic of a schist.

Secondary.—A term applied to rock minerals which are derived partially or completely from the alteration of other minerals in the rock.

Sedimentary.—A term designating those rocks that consist of particles deposited under water. Usually they show a bedded structure.

Shale.—A bedded rock formed by the consolidation of muds, silts, or clays.

Silica.—Oxide of silicon. SiO_2. Quartz is the commonest form of silica.

Siliceous.—Rich in silica or silica-bearing minerals.

Slate.—An argillaceous rock which is finely laminated and fissile, either due to very easy and uniform parting along bedding planes or (more properly) to cleavage planes developed as a result of compression (as in roofing-slate).

Strike.—The direction of the horizontal edge of inclined beds or other rock planes.

Till.—A stony or bowldery clay or rock rubbish formed by glaciers.

Trap.—A general term for igneous rocks of the dark-colored, basic types. The word is derived from the word trappa, meaning steps.

Trachite.—A compact igneous rock consisting, when fresh, mainly of potash feldspar in small, lath-shaped crystals, with various amounts of plagioclase, biotite, pyroxene, and hornblende.

Tuff.—A rock composed of the fine fragments blown into the air during volcanic eruptions.

Volcanics.—A name applied to igneous rocks which have been deposited at the surface of the earth either as flows of lava or as bedded masses composed largely of lava fragments. They may be acid or basic.

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